Los Alamos
NATIONAL LABORATORY

LA-14120-PR Progress Report
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D Division unfolds inside...

Decision Applications Division

2003–04 Progress Report

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LA-14120-PR Progress Report • Issued March 2004

Los Alamos
NATIONAL LABORATORY

Abstract

This progress report highlights the Decision Applications Division's achievements toward accomplishing Los Alamos National Laboratory's mission in 2003. The report presents an overview of the division, summary descriptions of the five D Division groups as well as the DoD Program Office, information on major research currently in process in the Division, and related appendices.

Additional information can be obtained by calling **(505) 667-4567** and by viewing the D Division web site at **http://www.lanl.gov/orgs/d/**. ▲

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Contents

Decision Applications Division

Division Overview

Decision Applications Division—An Overview

FROM THE D DIVISION LEADER

Los Alamos National Laboratory is one of the largest multiprogram laboratories in the world. The Laboratory develops and implements science and technology solutions for problems of global importance. The Decision Applications Division (D Division) is the decision analysis arm of the Laboratory. Our division tackles those problems which, because of their complexity, size, and national security implications, fall beyond the purview of other organizations. We have an exciting portfolio of projects and the state-of-the-art capabilities and facilities to execute these projects.

This year alone, we have made significant contributions in protecting our homeland from asymmetric threats, including weapons of mass destruction, and we are recognized for our key role in designing the nuclear reactors for space exploration. We have also worked very closely with internal and external organizations to enhance safety and reliability of our nuclear stockpile and to plan for the Laboratory's future growth.

I believe our success as a division is a direct result of our adherence to our core values—the excellence of our science and technology base; good stewardship of our programs; the academic and cultural diversity of our workforce; and our local and national community outreach. I am proud to lead such a dynamic organization. We have met past and current challenges and we are prepared to take on new endeavors in ensuring the safety and reliability of our nuclear stockpile, enhancing the security of homeland against terrorist threats, transforming our national defense forces, improving and protecting our nation's infrastructure, and expanding the nuclear technology base for space exploration. I consider it a privilege to work with the outstanding people in D Division.

The Decision Applications (D) Division is the science-based decision analysis arm of the Los Alamos National Laboratory (LANL). In fact, decision analysis capabilities are the unique thread of continuity that binds together this otherwise diverse division of 270 employees. The science and technology (S&T) base of D Division has been instrumental in enabling important institutional and national decisions with a direct impact on our national security.

D Division's Department of Defense (DoD) program office also plays a leading role in developing, coordinating, and executing DoD-sponsored research and development across the Laboratory.

Decision analysis, in the context of D Division, creates enhanced decision processes through integration of S&T and applies them to support critical Laboratory and national decisions. The broad-based S&T capabilities of D Division are vital to carrying out multi-disiciplinary assessments—an essential component of decision analysis of complex systems—and make us a unique division at Los Alamos.

We maintain and continually upgrade our capabilities by recruiting well-published staff, engaging in cooperative research with visiting faculty and students, and through active participation in Laboratory Directed Research and Development (LDRD) programs.

OUR VISION

Be the national leader in scientific decision support for national security.

OUR MISSION

Through science-based, multidisciplinary assessments, enable important national security decisions pertaining to the safety and reliability of the U.S. nuclear deterrent, homeland security, national defense transformation, and nuclear energy and environment.

OUR CAPABILITIES

D Division has seven core capabilities.

Computational Science

Computational science contributes to fundamental scientific understandings by applying computer-based representations to scientific and engineering problems. This work complements the traditional mechanisms of theory and experimentation in the scientific method. One of the unique capabilities of the Division is bringing together theoreticians and practitioners to translate ideas from theory into reality.

Engineering

Engineering is a strong component of D Division with fields of engineering varying from nuclear weapons engineering and manufacturing processes engineering to infrastructure reliability and safety engineering. Our engineers' abilities to work closely with modeling and simulation experts give us unique insights that we apply to designing advanced nuclear reactors for space exploration and to advancing homeland security technologies.

Nuclear Science and Engineering

Within D Division, nuclear science and engineering involves both developing nuclear analysis tools (e.g., MCNPX and TRAC) and utilizing such tools to design advanced or special purpose fission systems and to examine the safety and security of nuclear systems.

> *"The Laboratory Director claims that the Division's capabilities are extremely valuable…for which it is viewed as a 'crown jewel.' This committee endorses these assessments and asserts that D Division capabilities are, de facto, a capability of the nation. There are few, if any, external groups wherein the physical (and engineering) science and the decision science come under a common umbrella."*
>
> *External Division Review Committee (2003 Annual Report)*

Modeling and Simulation

The modeling and simulation (M&S) capability develops algorithms, models, and other software components to represent and study actual or theoretical systems of interest. The division delivers these as products in their own right or uses them in support of our analyses. Visualization is an important aspect of the M&S capability.

We also perform fundamental research into radiation transport, thermal and fluid dynamics and nuclear explosives materials response.

Operations Research/Systems Analysis

Practitioners of operations research/systems analysis (OR/SA) develop and apply tools and methods in order to understand the behavior of complex systems. The goals are to provide a rational basis for decision-making and to predict system behavior and improve system performance.

Qualitative Analysis

Qualitative analysis refers to an interdisciplinary set of computational and descriptive techniques and tools used to understand problems and develop solutions in domains that are inherently difficult to quantify. Included are methods for eliciting, representing, and integrating information from diverse sources.

Statistical Science

Distinguished by its multidisciplinary nature, statistics is the science of extracting scientifically meaningful qualitative and quantitative information sets and learning from data of all types. The ultimate goal is to support decision making under uncertainty, from decisions about basic scientific phenomena to public policy.

DIVISION THRUST AREAS

Nuclear Weapons

About a decade ago, the United States stopped producing new nuclear weapons, resulting in an aging stockpile. Nuclear weapons testing also ended, making it more difficult to assess the safety and reliability of that stockpile. Today we need improved analytical methods and tools to manage this overly committed and constrained weapons program.

To support the nuclear weapons programs, the Division provides a broad array of technical capabilities such as systems engineering, project risk analysis, uncertainty quantification, reliability and surety assessment, manufacturing process planning and analysis, nuclear safety analysis, stockpile planning, and facility planning. Our work is critical to both the short- and long-term success of the Laboratory's nuclear weapons program.

We lead several Laboratory activities related to

- systems engineering and risk analysis, and
- modern pit facility and technology planning.

We have a vital role in

- weapons reliability and quantification of margins and uncertainties (QMU),
- advanced concepts planning,
- military analysis and stockpile planning,
- nuclear facility planning, and
- nuclear stockpile surety modeling and analysis.

D Division currently supports a multitude of projects in the nuclear weapons arena. The nuclear weapons programmatic funding base is approximately $25M. We provide decision support to all aspects of the program. The major long-term objective is to better integrate the division into the decision-making structure of the Laboratory's nuclear weapons program. Keys to our success have been teaming with other divisions and encouraging career development for our staff.

Homeland Security

The 9/11 World Trade Center attacks raised concerns about our nation's ability to prevent and respond to terrorist threats and underscored the need for integrating our nation's disparate pieces of information (e.g., knowledge discovery and dissemination).

D Division is developing technologies to protect our criticalinfrastructures for assymmetic threats, including threats for WMD (weapons of mass destruction). We coordinate our efforts through CHS, and collaborate closely with B and N Divisions. One of our long-term objectives is to maintain D Division as the national center of excellence for modeling and simulation of critical infrastructure interdependencies.

The National Infrastructure Simulation and Analysis Center (NISAC) provides fundamentally new modeling and simulation capabilities for analyzing critical infrastructures, their interdependencies, vulnerabilities, and complexities. We apply our modeling, simulation, and systems analysis capabilities to designing optimum strategies to assess, mitigate, and respond to threats from weapons of mass destruction (WMDs).

D Division is also a national center of excellence in biosurveillance. This role is evidenced by the fact that several cities use our technologies (e.g., BASIS) to monitor and respond to radiation, nuclear, biological, and chemical threats. We are actively working to advance our technologies through collaborative research sponsored jointly by the Department of Homeland Security (DHS) and the Defense Threat Reduction Agency (DTRA).

DOD/Conventional Defense

As the DoD applies technologies to transforming defense, the Laboratory is playing a growing role in providing innovative science and technology solutions for conventional defense strategies. The Defense Transformation (DT) and Horizontal Integration (HI) initiatives require complex decisions regarding technology selection and qualitative modeling. This presents unique opportunities for D Division to re-establish itself as the integrator of defense systems and technologies developed across the Laboratory and across the country. Our DoD Program Office works diligently to develop programs in these areas, leveraging our existing capabilities. We also work closely with the Associate Directorate for Threat Reduction - Deputy Associate Director (ADTR-DAD) Office.

Energy and Environment

D Division has a strong background in the safety, security, and environmental aspects of nuclear energy. We support critical regulatory, policy, and planning decisions for our customers, and our programs support the NRC's Offices of Research, Reactor Regulation, and Nuclear Materials Safeguards and Security. We also support the Advanced Fuel Cycle Initiative for the DOE Office of Nuclear Energy. We are a national center of excellence for design and analysis of compact nuclear reactors.

The scientific foundation of this research is grounded in our technical expertise. Important current Division research activities include assessing vulnerabilities to terrorist threats in the nation's nuclear energy facilities, space nuclear reactor design and technology development, and systems modeling of advanced fuel cycle options.

The newly built D Division office building at LANL, completed in fall 2003.

Workforce Excellence

D Division has a workforce staffing plan that involves division and group managers, furthers the D Division strategic and group business plans, and implements the division's strategic hiring process. We encourage diversity in scientific approach and team membership, and foster a work environment that encourages creativity, academic freedom, fair evaluation of ideas, and celebration of achievements. We encourage professional development through mentoring, discipline associations, training, peer review, publications, and presentations. The framework for workforce planning includes identifying strategic staffing needs based on our division's thrust areas and group business plans. Core capabilities are reviewed and critical skills are identified as needed to enhance the division's core capabilities in concert with thrust area goals. D Division strives to hire our next generation of scientists to increase our technical depth across disciplines.

Facilities

D Division facilities primarily support office and computing requirements. In November 2003, the division dedicated a

$5M general purpose building that is now housing approximately 100 employees in the statistical sciences and stockpile complex modeling and analysis groups. Strategically located in TA-3 near the Nonproliferation and International Security Center and the Nicholas C. Metropolis Center for Modeling and Simulation, this secure, 22,000-square-foot building provides a much-needed improvement of work environment for our staff and will help us attract new staff with critical skills to support the Laboratory's mission. This new facility is part of the infrastructure revitalization at the Laboratory. The D Division Visualization Laboratory is located in TA-3 and offers high-performance graphics processors; a range of visualization and graphics tools; a large-screen, stereo-enabled projection environment; quadraphonic sound; and some motion tracking for virtual reality applications.

We are developing our long-term, facilities strategic plan to consolidate our workforce into one central science complex to achieve cost savings and new construction to accommodate projected mission need.

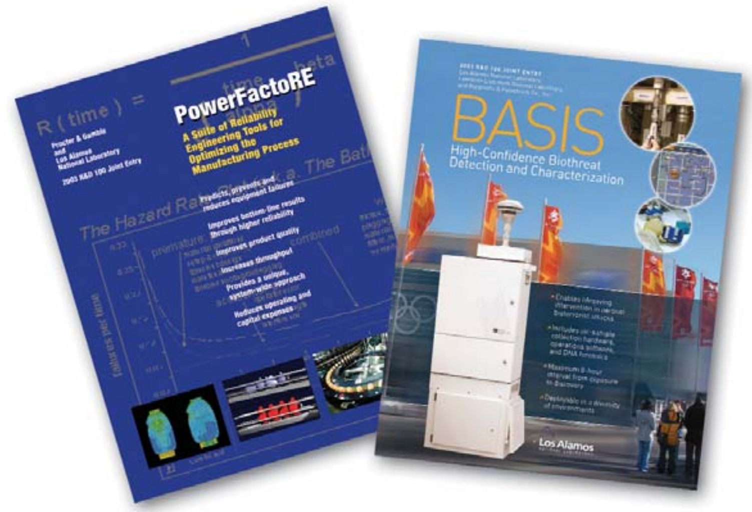
SPECIAL RECOGNITION

This past year D Division received two R&D 100 Awards for our statistical analysis and bio-detection research.

The R&D 100 awards program is designed to honor significant commercial promise in products, materials, or processes developed by the international research and development community. Each year, *R&D Magazine* recognizes the world's top 100 scientific and technological advances with awards for innovations showing the most significant commercial potential. D Division received two of the eight projects that were selected within the Laboratory.

PowerFactoRE is a suite of reliability engineering tools designed to optimize manufacturing processes. The result of a collaboration between the Laboratory and Procter & Gamble, it comprises a unique set of methods, statistical and analytical tools, simulation software, procedures, and training that enables manufacturing line managers to understand reliability losses and to correct seemingly isolated defects in the manufacturing process. This work was done in D Division's Statistical Sciences Group.

Biological Aerosol Security and Information System, commonly known as BASIS, is a biothreat detection and characterization technology for protecting civilian populations against terrorist aerosol releases of micro-organisms capable of inducing lethal infection. BASIS allows the detailed identification, localization, and time-of-release pinpointing of select aerosol-released organisms. This precise detection facilitates the rapid treatment of exposed individuals, often even before symptoms appear. This work was done in D Division's Systems Engineering and Integration Group. ▲



Covers of the division's two R&D 100 award winners for 2003.

Decision Applications Division

2004 Division Review Committee

2004 Division Review Committee

THE COMMITTEE

The 2004 Decision Applications Division Division Review Committe members includes the following:

Nozer D. Singpurwalla (Committee Chair)

The George Washington University, Professor of Statistics and Distinguished Research Professor

Dr. Singpurwalla has been a visiting fellow at St. Hugh's College, University of Oxford, U.K., and has held visiting professorships at the Santa Fe Institute; Carnegie-Mellon University; Stanford University; the University of Florida, Tallahassee; and the University of California, Berkeley. In 2002, he was an invited professor at Université de Bretagne-Sud in Vannes, France. In 1991, Dr. Singpurwalla was the first C. C. Garvin Visiting Endowed Professor in the Mathematical Sciences at the Virginia Polytechnic Institute and State University. He is a fellow of the Institute of Mathematical Statistics, the American Statistical Association, the American Association for the Advancement of Science, and an elected member of the International Statistical Institute. Dr. Singpurwalla's areas of expertise are applied probability and Bayesian statistics; reliability theory, warranties, and quality control; time-series analysis; fault-tree analysis; filtering theory; uncertainty in expert systems; and failure data analysis. For his contributions to the theory and applications of reliability, he received the U.S. Army Research Office's S. S. Wilks Memorial Award. Dr. Singpurwalla received his Ph.D. from New York University in 1968.

Massoud Amin

University of Minnesota, Professor of Electrical and Computer Engineering

Dr. Amin holds the H.W. Sweatt Chair in Technology Leadership and is the director of the Center for the Development of Technological Leadership at the University of Minnesota in Twin Cities. His research focuses on global transition dynamics to enhance resilience and security of national critical infrastructures. Dr. Amin is extremely knowledgeable in the critical infrastructures area. For five years before joining the University of Minnesota, Dr. Amin held several positions at the Electric Power Research Institute (EPRI) in Palo Alto, California, including area manager of infrastructure security, grid operations/planning, and energy markets. He directed all security-related research and development at EPRI, including the Infrastructure Security Initiative (ISI) and the Enterprise Information Security (EIS) areas. Before October 2001, he served as manger of mathematics and information science at EPRI, where he led strategic research in modeling, simulation, optimization, and adaptive control of national infrastructures for energy, telecommunications, transportation, and finance.

Paul Bracken

Yale University, Professor of Management and Political Science

Dr. Bracken teaches courses at Yale University on international strategy and organization, global technology, and management of innovation. In addition, he is responsible for the required MBA course on the strategic environment of management. Before joining the Yale faculty, Professor Bracken was on the senior staff of the Hudson Institute, a think tank, for 10 years. He is currently writing a book called *Technology and Grand Strategy*. Professor Bracken is a member of the Council on Foreign Relations and serves on the Chief of Naval Operations Executive Panel. He holds a Ph.D. in operations research from Yale University.

Daniel G. Brooks

Arizona State University, Associate Professor of Statistics

Dr. Brooks has 20 years' experience applying decision and risk analysis to problems in the development of decision-making processes and risk-based strategy formulation for both the federal government and private industry. For the past eight years (until December 1999) he served as senior scientist at Applied Decision Analysis, Inc., and for the past two years as a director for PricewaterhouseCoopers' Financial Advisory Services Group. Dr. Brooks is past associate editor, vice-president, and a member of the board of directors for Decision Sciences, as well as a member or past member of the American Statistical Association (ASA), the Decision Sciences Institute (DSI), and the Institute for Operations Research and Management Science (INFORMS). He has a Ph.D. in decision sciences from Indiana University.

Geoffrey Fox

Indiana University, Professor of Computer Science, Informatics and Physics, Director of the Community Grids Laboratory

Dr. Fox is a pioneer in the development and application of parallel computers and now focuses on grid computing. Previously at Florida State University, Syracuse University, and Caltech, he was professor of physics, associate provost for computing, and dean for education computing. Dr. Fox was born in Dunfermline, Scotland, and received his Ph.D. in theoretical physics from Cambridge University in 1967.

Stephen J. Guidice

Independent Consultant

Mr. Guidice has more than 30 years of nuclear weapons program knowledge and experience. He is formerly the head of the Office of National Defense Programs at the US DOE Albuquerque Operations Office. In that capacity, he managed the nuclear weapons production, maintenance, dismantlement, quality assurance, nuclear explosive safety, surveillance, and reliability assessment programs with an annual budget of more than $2B. His responsibilities included managing and integrating the technical activities of three weapons laboratories, seven large commercial contractors operating the weapons production plants, the Department of Defense, and foreign governments. His other senior executive service positions at ALO included director of weapons production, director of weapons quality, and head of the Office of Energy, Science and Technology. Since 1998, he has been an independent consultant advising the weapons laboratories, weapon production plants, and Congress. He received his B.S. in engineering in 1968 and his M.S. in management in 1972, both from the Rensselaer Polytechnic Institute in Troy, NY.

The 2003 D Division Division Review Committee.

Charles M. Herzfeld

Center for Strategic and International Studies, Senior Associate

Dr. Herzfeld has served as director of the Advanced Research Projects Agency (ARPA) when the ARPAnet was started, as vice president for research and technology at ITT Corporation, as director of defense research and engineering in the Department of Defense, and as senior consultant to the Science Advisor of the President. He has been a member of the Chief of Naval Operations Executive Panel since its formation in 1970. He has served on the Defense Science Board and the Defense Policy Board. He has testified frequently before Congress and written and lectured in the subjects of defense technology and policy, information technology, and high-performance computing. Dr. Herzfeld has a Ph.D. in physical chemistry from the University of Chicago.

Jon R. Kettenring

Former Executive Director of the Mathematical Sciences Research Center (MSRC) at Telcordia Technologies

Dr. Kettenring joined Telcordia in 1983 after 15 years in the Statistics and Data Analysis Research Department at Bell Laboratories in Murray Hill, where he engaged in and supervised statistics research. He is a fellow of ASA and AAAS and an elected member of the International Statistical Institute. He has represented a “statistics in industry” perspective in a variety of national and international assignments. These include president of the American Statistical Board on Mathematical Sciences of the National Research Council, board of trustees of the National Institute of Statistical Sciences, and board of directors of the Interface Foundation of North America. Dr. Kettenring has a B.S. and M.S. from Stanford University in statistics and Ph.D. from the University of North Carolina in statistics.

Per F. Peterson

University of California at Berkeley, Professor and Chair, Department of Nuclear Engineering

Professor Peterson manages the UC Berkeley Thermal Hydraulics Research Laboratory. His research focuses on problems in energy and environmental systems, including inertial confinement fusion, advanced reactors, high-level nuclear waste processing, and nuclear materials management. Professor Peterson has served on the UC Berkeley College of Engineering strategic planning committees, as well as chairing the College Committee for Undergraduate Studies. He has contributed to the *Journal of Heat and Mass Transfer* as an associate editor and currently serves as an editor for *Experimental Heat Transfer*. Professor Peterson is a Fellow of the American Nuclear Society, and from 1996 to 1997 he served as chairman of its Thermal Hydraulics Division. He has made contributions as a consultant on the design of the Westinghouse AP-600 and GE ESBWR advanced reactors. He received a Ph.D. from the University of California-Berkeley in 1988.

James Stanley Tulenko

University of Florida, Professor, Nuclear and Radiological Engineering

Professor Tulenko is currently the director of the Laboratory for the Development of Advanced Nuclear Fuels and Materials at the University of Florida. He is a fellow of the American Nuclear Society and has received such distinguished awards as the Arthur Holly Compton Award of the American Nuclear Society (ANS) for outstanding contributions to nuclear science and technology Education, the Mishima Award of the ANS for Outstanding Research in the areas of Nuclear Fuels and Materials, the Glen Murphy Award of the American Society for Engineering Education as the outstanding nuclear engineering educator, and the Silver Anniversary Award of the ANS for outstanding contributions to the nuclear fuel cycle in the first 25 years of the ANS. He is currently the vice president/president-elect of the ANS. His areas of interest are nuclear engineering, nuclear fuel management, nuclear waste, nuclear fuel manufacturing, systems engineering, radiation effects on materials, robotic maintenance in hazardous environments, and computer simulations.

UC Representative

Dr. John Ahearne

Dr. Ahearne received his Ph.D. in physics from Princeton University. He has held a lengthy record of government service, including the Air Force Special Weapons Center, the Air Force Academy, the Office of the Secretary of Defense, the White House, and the Nuclear Regulatory Commission. Currently he is at Sigma Xi and Duke University and serves as the chair of the National Research Council's Board on Radioactive Waste Management and is a member of the University of California President's Council. ▲

Decision Applications Division

Group Overviews

Decision Applications Division Organization

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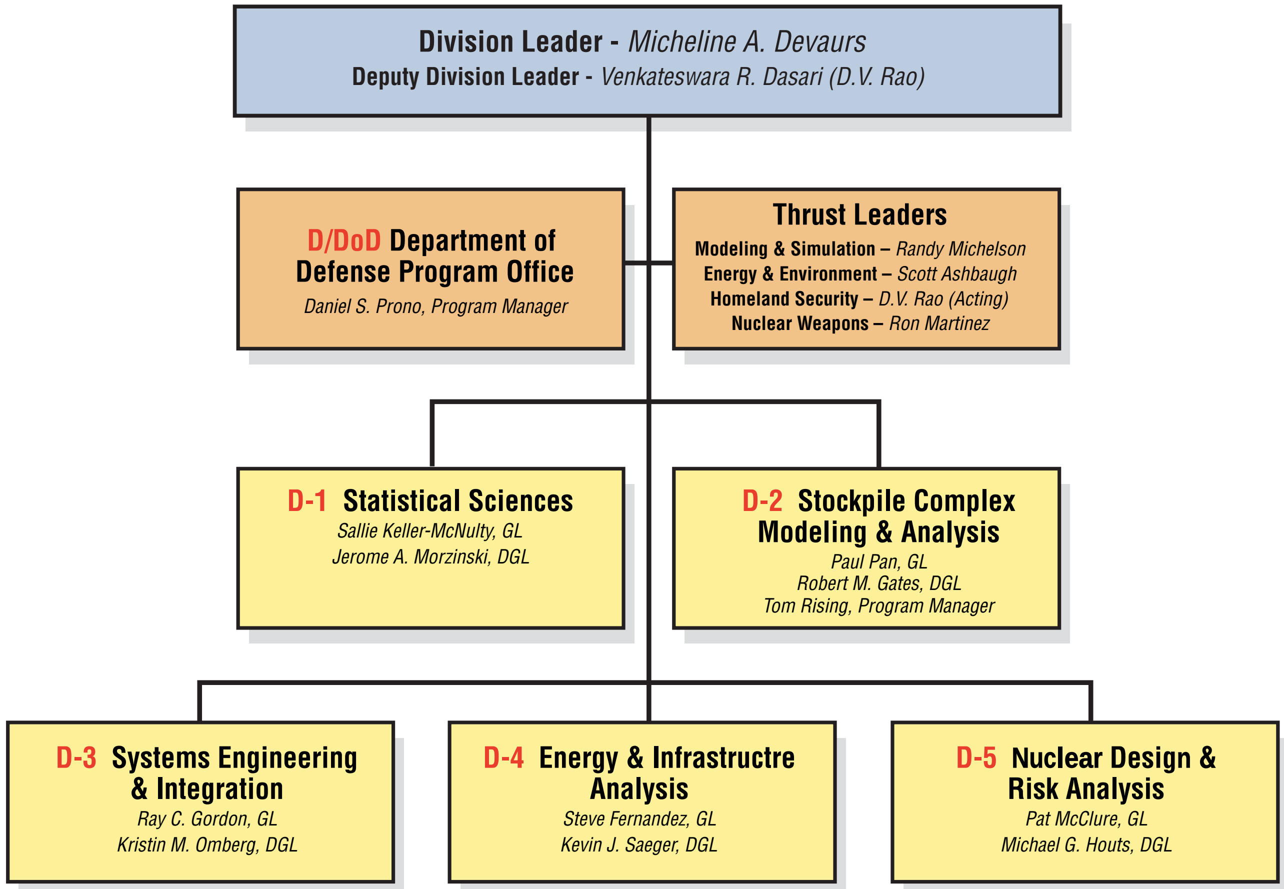
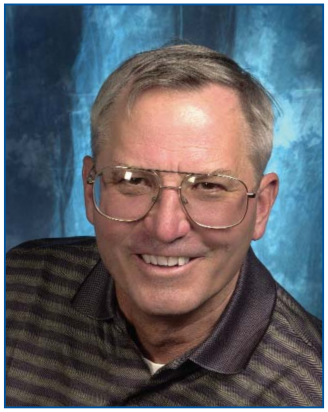


Decision Applications Division Organization Chart (2/04)

Decision Applications Division Management Team



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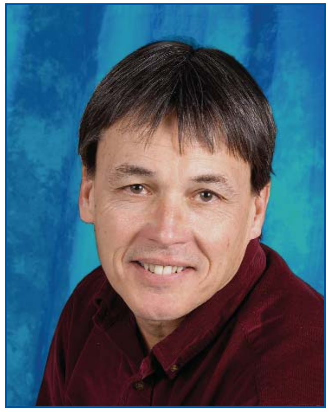

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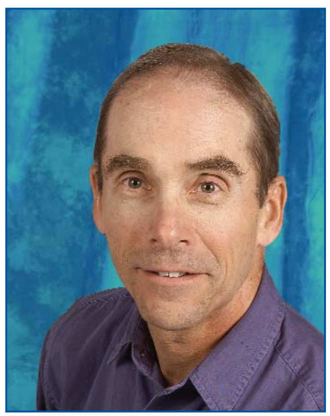

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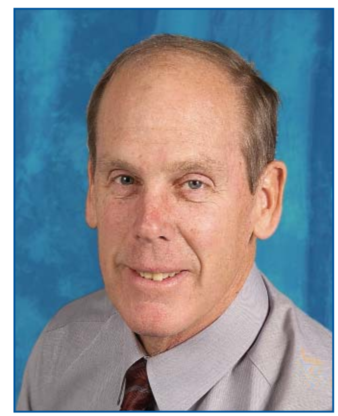

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D-1 Statistical Sciences

The Statistical Sciences Group was formed in 1967 to enhance the quality of research at the Laboratory by providing a center of statistical excellence. We work with scientists, engineers, and policy makers both within and outside of the Laboratory to bring statistical reasoning and rigor to multidisciplinary scientific investigations and to apply them to problems of national importance. Our work includes developing, understanding, representing, and communicating cutting-edge statistical techniques for decision making under uncertainty. The group has extensive experience in developing techniques for collecting, analyzing, combining, and making inferences from diverse qualitative and quantitative information sets such as experiments, observational studies, computer simulations, and expert judgment.

Core competencies of the group include computationally intensive statistical methods, Bayesian methods, hierarchical methods, statistical reliability, uncertainty quantification, experimental design, spatial-temporal methods, degradation/aging methodology, Monte Carlo methods, applications of statistics to general science, and knowledge discovery and dissemination.

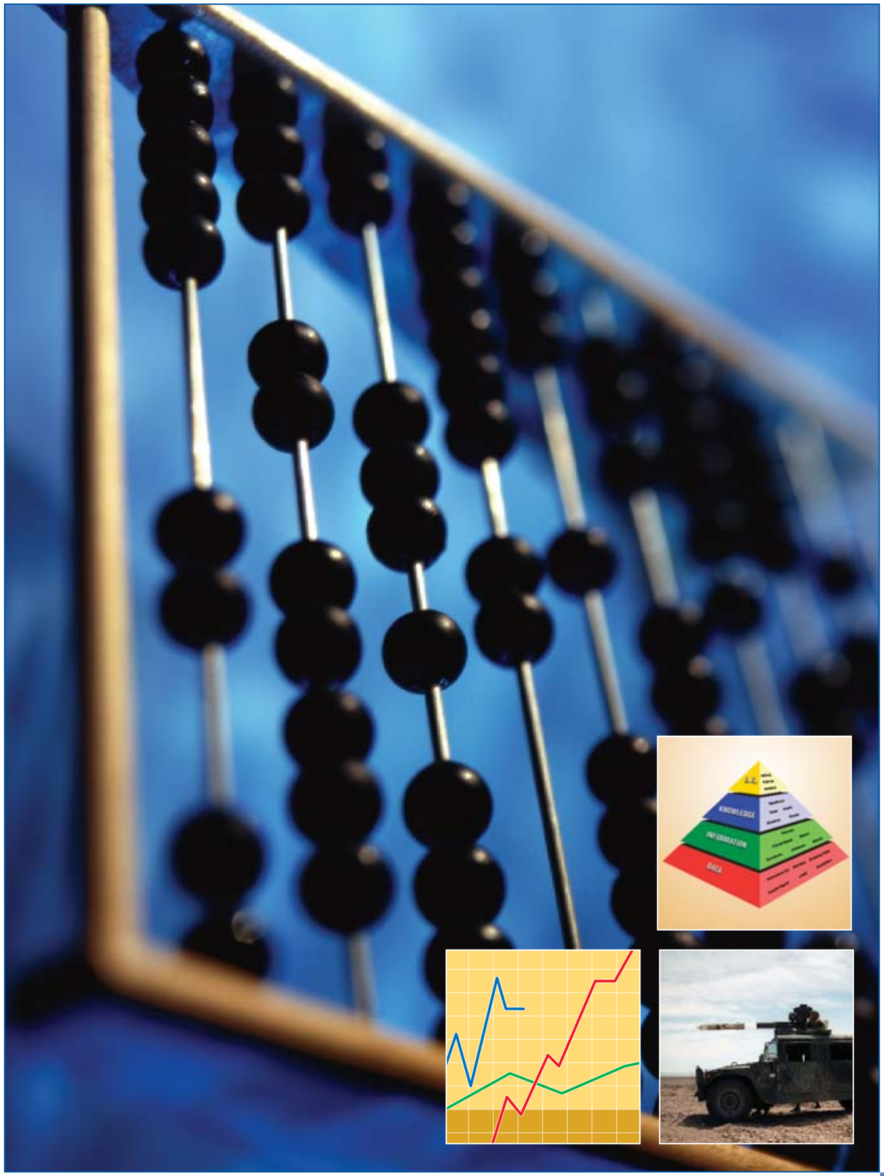
FOCUS AREAS

Biological Sciences Applications

This research involves managing and analyzing information about biological systems. For example, to develop early warning and surveillance systems for biological threat agents, we may be interested in rapid identification of organisms and pathogens, identification of geographic soil locations and background microorganism content, or classification of ecological microclimates. Research involves large-scale epidemiological simulation, genetic data analysis, and ecological and environmental statistics.

Computational Statistics

Researchers in D-1 need computational environments to do rapid prototyping of new methods, particularly Markov chain Monte Carlo (MCMC)-based methods. We employ modern techniques from statistics, computer science, and applied mathematics in search of such environments. The complex problems we solve often involve massive data sets with characteristics (e.g., many dimensions, nonhomogeneity) that make them difficult to tackle with traditional statistical methods. These analytical methods are computationally intensive, and often make use of visualization tools to help understand the structure of large data



sets. Currently, we are developing an extensible object-oriented system, "YADAS," to perform these analyses.

Information Integration Technology

Information integration technology (IIT) is a framework of processes and methodologies used to combine and integrate information from diverse sources to produce traceable, mathematically rigorous assessments of system performance. The framework is flexible (e.g., real data, experimental data, results of computer simulations, and expert opinion can all be used) and supports a range of objectives from estimating reliability to decision-making under uncertainty. We create qualitative representations of complex systems and then, with the help of automation tools, transform those into quantitative, statistical models to produce full distributions, with uncertainties, for performance metrics. We are using IIT in collaboration with partners from the weapons community, from industry, and from the DoD.

Monte Carlo

Current D-1 research on Monte Carlo methods is focused on the use of biasing (i.e., importance sampling) techniques to improve convergence in simulations of time-dependent physical processes, as conducted in Stochastic Simulation/Monte Carlo Methods. Coupling this algorithm with importance sampling has been a part of the statistical physics work in which configurations of a large system are visited using MCMC. Importance sampling is useful in improving the mixing of the chain and aids in reducing variability. Examples of recent work include simulating physical processes such as the movement of pollutants, neutrons, or agents; rare event simulation; and simulating from distributions with widely separated peaks.

Reliability

Reliability analysis is the name given to investigations into system performance and availability and how they change with time or with improved materials or processes. It involves modeling systems when objective test data are scarce or nonexistent, as with one-of-a-kind questions. Determining optimal experimental design is often part of the analysis. We analyze information that may come from real-world data, expert opinion, computational models, and physical experiments and attempt to understand the relationship between system test conditions and performance. We apply reliability analysis to problems in industry, defense, and other government agencies. We use many techniques, such as hierarchical Bayes models, Poisson processes, and MCMC.

Statistical Population Bounding

The basic population bounding problem is to determine bounds that contain a desired fraction of a population. Whereas confidence limits bound the mean with a specified level of confidence and prediction limits bound individual predicted points, tolerance bounds contain a specified proportion of a population with a desired confidence. In extensions from the basic problem, we consider distributions as they age over time, multiple populations, assessment of measurement processes, and bounds on probabilities. Examples of areas where we have applied population bounding include environmental exposure, material properties, measurement and production system variation, and nondestructive measurement techniques.

Uncertainty Quantification

We support Laboratory certification efforts by developing methodologies to quantify uncertainty in all aspects of stockpile performance. We model and analyze both physical data and results of computer simulations. When analyzing the results of computer models, we are concerned with how far apart the actual outcome and predicted outcomes are likely to be at a specific point in light of evidence at other specified points. Methods developed and applied include Bayesian (data combining) methods, analysis of expert judgment, linear and nonlinear modeling, multivariate analysis, and analysis of variance components. We apply these methods in a variety of areas, from sampling issues that arise in core surveillance to resolution of significant findings.

POINT OF CONTACT

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D-2 Stockpile Complex Modeling and Analysis

The Stockpile Complex Modeling and Analysis Group, D-2, develops modeling tools, systematic analyses, and integrated planning options through the systems engineering process to assist the weapons complex and the nation in formulating informed and timely decisions; this mission is achieved using the group's analytical capabilities as well as its technical expertise.

The systems engineering mission is accomplished through facility modeling, nuclear planning and analysis, the pit manufacturing capability program, modern pit facility (MPF) manufacturing systems modeling and analysis, systems analysis and planning, and project risk management.

FOCUS AREAS

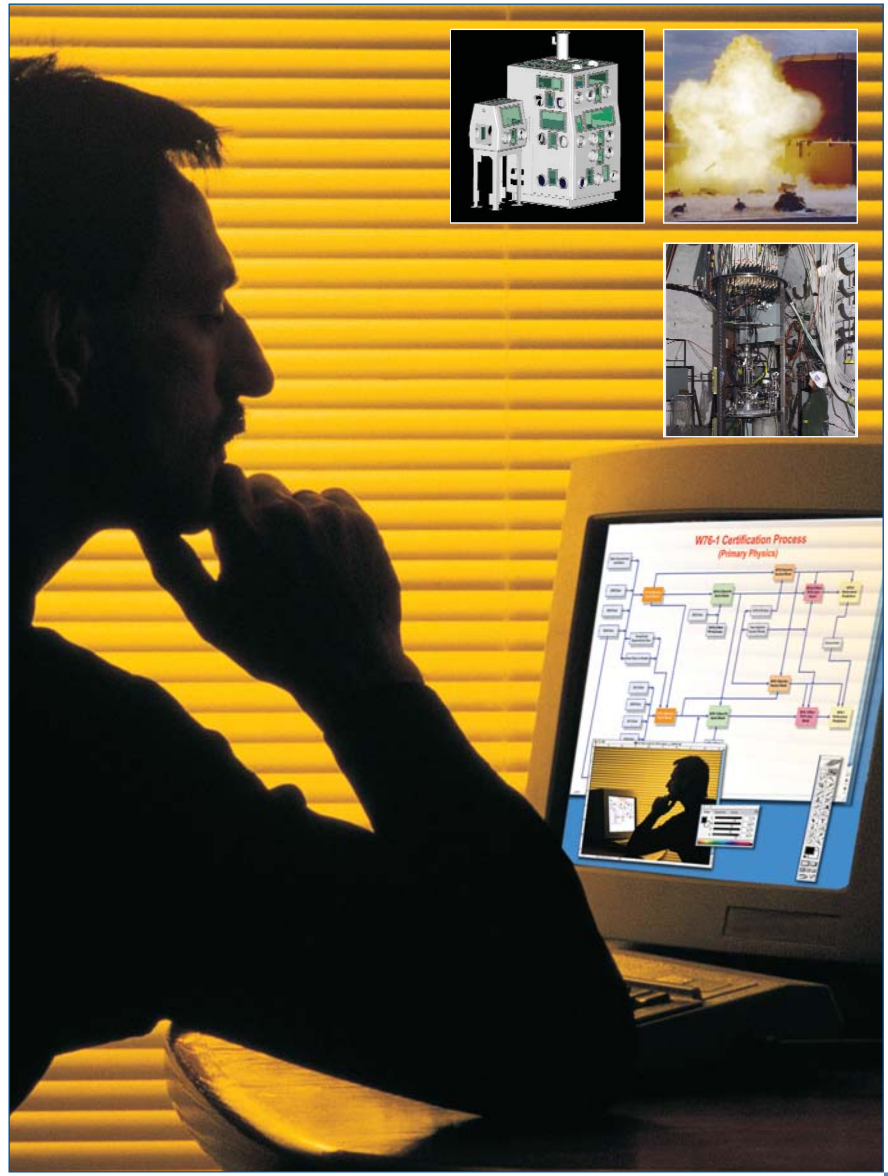
Non-nuclear Facility Planning and Analysis

The Non-nuclear Facility Planning and Analysis Team members have an extensive history in discrete event simulation modeling and systems engineering. Within the Laboratory, this work has been applied to the high-power detonator production facility expansion as well as to non-nuclear component production. A model of the Laboratory's high-power detonator facility expansion guided Dynamic Experimentation (DX) Division management in setting equipment requirements and designing procedures to transition into an expanded facility. Currently, we are developing a model that integrates all of the many production operations for non-nuclear components at the Laboratory. The model will provide a bird's-eye view of operations and processes across the geographically dispersed facilities in Materials Science Technology (MST) and Engineering Science Applications (ESA) Divisions.

TA-55/PF-4 Planning and Analysis

Members of the Nuclear Facilities Planning and Analysis Team are leading the detailed planning and analysis for improvements in the Laboratory's existing pit production and plutonium research infrastructures. With the aging Plutonium Facility (PF-4) and many different projects competing for limited space, NMT Division senior managers have asked D-2 to help in the planning and decision-making process for allocating limited budget, personnel, and space to ensure that the Lab meets or exceeds National Nuclear Science Administration (NNSA) programmatic requirements over the next five to ten years.

The planning and analysis skills that the team used to provide a top-level roadmap for the PF-4 and TA-55 project are now being used to develop detailed options for modifications to individual



rooms and projects planned for fiscal year 2004

Team members have worked with Nuclear Materials Technology (NMT), Chemistry (C), Project Management (PM), and Security (S) Division managers to achieve consensus on a roadmap for equipment and infrastructure upgrades to PF-4. The roadmap was presented to senior NNSA officials, resulting in a restructuring of planned funding for PF-4 infrastructure improvements in FY04.

Complex Manufacturing Systems Modeling and Analysis for Modern Pit Manufacturing

The Complex Manufacturing Systems Modeling and Analysis Team uses a combination of modeling, simulation, and analysis tools to perform a systematic, detailed analysis of manufacturing systems for the MPF. The team gathers data and then performs a detailed analysis of various customer scenarios using to provide data-rich numerical and graphical representations of overall system performance. For example, the system can be operated virtually to evaluate if green-field new-builds, modifications, expansions, or transformations can be economically or efficiently completed and operated as designed.

Project Risk

Programmatic systems engineering and risk analysis services are needed wherever mission success depends upon the performance of programs or projects involving the integration of complex systems. The Project Risk Team uses a comprehensive systems-based project risk analysis method and has applied it to more than 20 major projects.

A typical risk analysis produces cumulative probability distribution functions that describe the confidence levels for achieving a desired result for a given project. D-2's analyses identify the most important contributors to risk, and hence, the most promising candidates for mitigation actions. Quantitative project risk analysis results can also be used to provide a rational basis for setting baseline schedules and cost targets and for establishing appropriate contingencies for projects.

The Risk Team is increasingly assisting in early program/project definition and decision-making. This systems engineering-level work involves many of the same methods and tools but often requires more rapid response and yields less quantitative results.

Risk analysis results have been applied to the following projects:

- Qual 1 pit
- Interim capacity upgrades program integration
- Physics analysis
- Nuclear materials safeguards and security upgrades

The Project Risk Team also assists the Laboratory's Enterprise Project (EP) Strategic Planning Team with a risk-based prioritization of alternative path forward strategies for EP implementation.

Pit Manufacturing

A D-2 team manages the LANL Pit Manufacturing Capability Program. As such and under the direction of NNSA, they are the complex-wide responsible party for reestablishing the United States' pit manufacturing capability and assuring the U.S. is prepared to manufacture reserve pits. This team identifies, develops, and deploys technologies to improve and update the pit manufacturing process. One of the main goals is to sustain a modern pit manufacturing capability that extends beyond the W88 Manufacturing and Certification Program and into pit manufacturing within the enduring stockpile.

W76-1/Mk4A Project Integration

A multidisciplinary team has been assembled to provide overall project integration for the W76-1/Mk4A Life Extension Project (LEP) at Los Alamos. The LEP Team is completing Phase 6.3 of the refurbishment on the Lab's portions of the W76/Mk4 warhead with a first production unit expected in 2007. The Project Integration Team provides tools and support to the LEP and the Project Director to establish and maintain control of a $250+M, eight-year effort.

The team maintains the schedule and cost baselines for the LEP; manages the D-2 risk management personnel; and manages the project support personnel from several Laboratory organizations.

Planning and Integration Office

The Planning and Integration Office was established in an effort to capture the work funded in by the Weapons Programs so that budget and priorities could be adjusted to meet the changing NNSA requirements. D-2 works with the Accelerated Strategic Computing Initiative (ASCI) and readiness in technical base and facilities (RTBF) to define their work in terms of projects.

The primary focus are the weapons programs in the Weapons Engineering and Manufacturing (WEM) and Weapons Physics (WP) Directorates; however, the Laboratory's Threat Reduction (TR) Directorate is also initiating an effort based on the nuclear weapons example. Primavera Enterprise (P3e) software identifies interrelationships between the different kinds of scope, work activities, and resources, and evaluate impacts based on these relationships.

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D-3 Systems Engineering and Integration

The Systems Engineering and Integration Group, D-3, uses an interdisciplinary approach to complex systems analysis in the following programmatic areas: biological defense and countermeasures; conventional and nuclear military systems; and nuclear systems, primarily in the area of advanced fuel cycle technologies. We develop the models, simulations, and other requisite analytic tools necessary to capture the complex relationships and system-of-systems interdependencies of the problems presented to us. This end-to-end, system-of-systems approach and operational perspective distinguishes our work and creates the unique niche for a demanding customer set that includes the DoD and DHS operational communities.

The group received a 2003 R&D 100 Award for creating the Biological Aerosol Sentry and Information System (BASIS) program, which is a key part of the National BioWatch Program announced during President Bush's State of the Union address in 2003.

Core competencies of D-3 include nuclear weapon effects, software system design and development, systems analysis, systems integration, distributed computation, strategic studies, and fusion systems and fuel cycles.

FOCUS AREAS

Systems Analysis and Integration for Homeland Defense

D-3 supports the DHS and the NNSA by providing systems analyses in the areas of biological countermeasures (BASIS, BioNet, and associated programs) and radiological countermeasures (the Maritime Study). D-3 also provides systems integration expertise for multilayer, systems-of-systems for homeland security including the BASIS, BioWatch, and Unconventional Nuclear Warfare Defense (UNWD) projects.

Systems Analysis, Engineering, and Code Development for Defense Applications

D-3 supports NNSA and the DTRA by providing systems analyses and engineering for stockpile stewardship and advanced concepts weapons systems such as the Advanced Concepts Technology Development (ACTD) and Tunnel Target Defeat (TTD).

D-3 also provides systems analyses and modeling and simulation software for conventional weapons applications such as the Graphical Interface and Aggregate Control (GIAC) project. The GIAC team supported numerous large-scale joint military exercises in Europe and Korea, for which they won a

Laboratory Distinguished Performance Award and laudatory comments from high-level military commanders.

Systems Analysis and Code Development for Nuclear Fuel Cycle Applications

D-3 provides systems analyses and simulation code development in support of the Advanced Fuel Cycle program and the fundamental science of transmutation of nuclear waste.

Nuclear Weapons Studies Requirements and Analysis

Under the broad category of nuclear weapons studies, institutional analyses are performed to support the formulation of several Laboratory positions including stockpile planning, advanced concepts analysis, and weapons requirements. Weapons studies have addressed a broad range of nuclear weapons concerns ranging from estimating stockpile size in a START III environment and tritium requirements over the next 20 years, to plutonium-pit production in the twenty-first century and integrated security and use control risk assessments, to weapons effects analysis and lectures on the history of the weapons programs for the Laboratory's Theoretical Institute of Thermonuclear and Nuclear Studies (TITANS).

Maintaining a broad-based nuclear weapons analysis capability is critical to the identifying the pressing issues and making recommendations to the decision makers who are guiding the weapons programs.

Current projects utilizing this capability are the robust nuclear earth penetrator (RNEP) advanced concepts feasibility study, reliability replacement warhead planning, Earth penetrator weapons effectiveness tools development, and long-term nuclear weapons strategy and technology studies.

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D-4 Energy and Infrastructure Analysis

The Energy and Infrastructure Analysis Group, D-4, performs basic and applied research to secure the nation's energy infrastructure. Our staff works in close cooperation with physicists, engineers, mathematicians, statisticians, and economists to develop large-scale yet detailed models of these industries and infrastructures. Our macro models and micro simulations quantify the physical, operational, and economic behavior of energy networks including the generation, transmission, and distribution of electric power, natural gas, oil, coal, and nonenergy infrastructures important to energy security (transportation, water, communications, and public health). Often these models are combined within interdependency, optimization, and risk assessment frameworks.

Our research activities include developing and testing new technologies for the next generation of electrical grids. These will be integrated into a complete M&S architecture. The programs supporting the next-generation electrical grid must sense the health of the grid and input this data into new models and tools. D-4 also helps govern the DOE's Energy Infrastructure Training and Analysis Center (EITAC) through a steering group that includes Sandia and Argonne. The first EITAC visualization capabilities will be Los Alamos products.

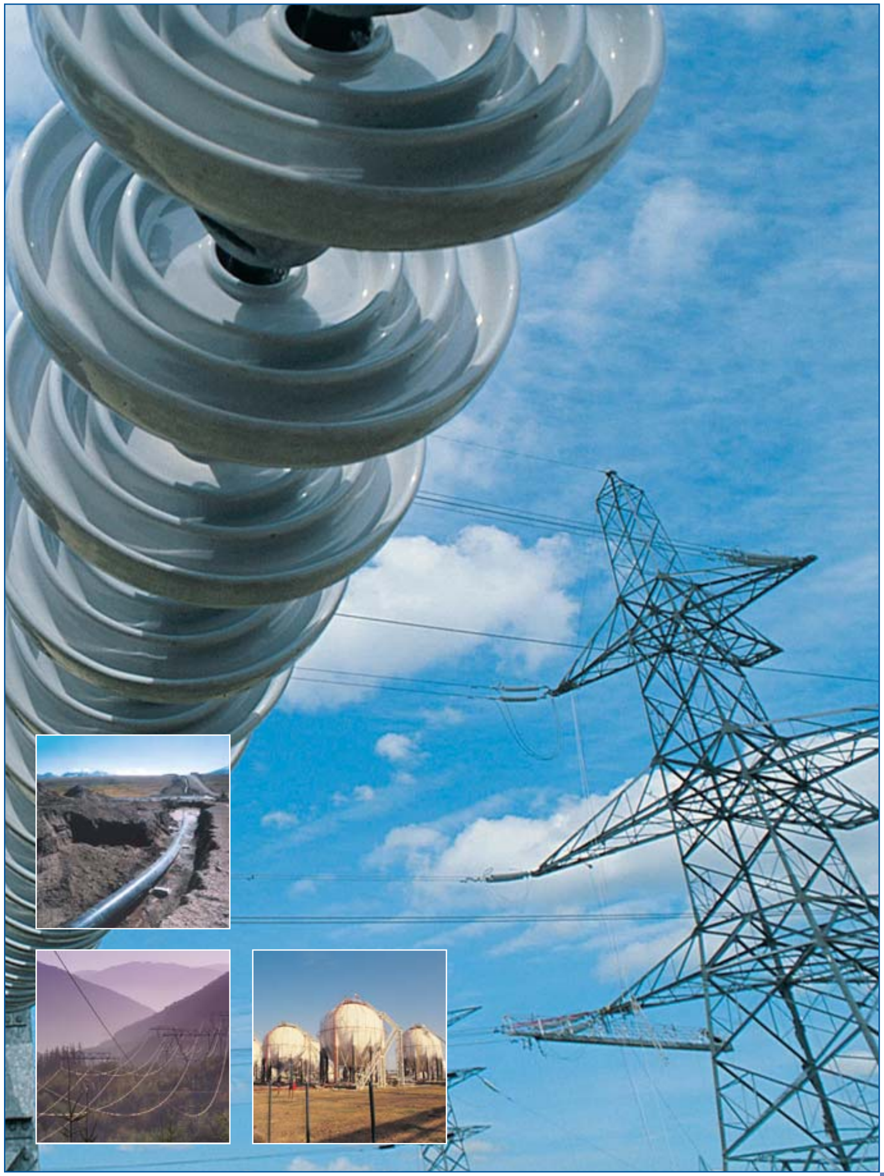
D-4's core competencies include infrastructure modeling, simulation, and analysis, economic and financial analysis, air quality, environmental analysis, and energy and transportation systems.

FOCUS AREAS

Economics

The economics team provides the Laboratory and the nation with economic expertise in two primary areas: economic studies for institutional decision making and economic models for inclusion in simulations of complex infrastructures. The institutional analysis provides information to Laboratory decision makers on the economic aspects of proposed actions. Economic considerations underlie a significant number of the decisions made in areas such as energy, transportation, and communications. To adequately simulate the characteristics of these sectors, economic considerations must be included in the simulation.

Institutional analysis at Los Alamos encompasses an eclectic collection of projects and analysis techniques. Project areas include macroeconomic modeling, monetary and financial flows analysis, natural resource and energy economics, environmental analysis, and engineering economics. The economics team has been providing economic analysis for the facility upgrades and restructuring



planned in the Laboratory's new facilities plan.

This broad agenda necessitates a variety of analytical methods. Our economists have used general equilibrium models, regression, statistics, data mining, linear programming, and other methods as needed to complete commissioned analyses.

The team has developed simulations to model the physical aspects of national infrastructure systems such as transportation networks and energy transmission grids. Increasing the versatility of these simulations to model future conditions requires including of economic considerations.

Data Management and Information Systems

The data management and information systems effort provides the national infrastructure and network data used in the NISAC simulations and for DoD, DHS, and DOE programs outside the Laboratory. Network data from this program has provided the real transportation data for TRANSIMS, created the needed data source for Clean Coal Technologies, and provides the source data for the division's simulations and analyses.

The transportation simulator TRANSIMS requires data that defines various road networks. Road networks for Dallas/Ft. Worth, Portland, and Chicago were developed under this program. Research is underway on methods to streamline the generation of road networks for TRANSIMS.

The Clean Coal Technology Demonstration Program is a unique partnership between the DOE and industry. This program's primary goal is to successfully demonstrate a new generation of advanced coal-based technologies, with the most promising technologies moving into the domestic and international marketplace. The demonstrations are at a scale large enough to generate the data needed to make judgments about the commercial viability of a particular process and will improve global environment and energy security by using technologies and services provided by U.S. industry.

Visualization

The D-4 Visualization Team has experience in many areas of scientific, geographic, statistical, and information visualization. Using commercial tools such as geographical information systems (GIS), mathematical analysis tools, simulation systems with graphical or visual front ends, or by developing custom software, the team helps analysts, simulation scientists, and decision makers understand, share, or present their data more effectively.

The team also operates the D Division Visualization Laboratory, which offers high-performance graphics processors; a range of visualization and graphics tools; a large-screen, stereo-enabled projection environment; quadraphonic sound; and some motion tracking for virtual reality applications.

The Visualization Team collaborates with other laboratories, industry, and academia in researching advanced perceptualization, which includes more than just visual sensory modes, a sense of "presence" or "immersion," and the use of richer cognitive models beyond merely geometric or psychometric in a readily understandable format.

Network Analysis

This D-4 team handles analytics tasks that characterize network performance of a diverse set of infrastructures such as electric, gas, pipeline, telecommunications, and transportation networks. Analyses focus primarily on normal or off-normal conditions arising within a regional or local network. Site-specific analysis can also include service and outage area estimates, as well as estimates of outage duration based upon component criticality considerations.

Appropriate interpretations of system-level metrics that result in degradations to commercial delivery capability and to varying system conditions throughout a typical year are reviewed. Network analyses often includes three components: regional system, local operational area, and on-site. These analyses use both quantitative and qualitative processes. Electric networks are analyzed to identify transmission/subtransmission lines that are critical for power transfer and subtransmission system configuration. The analysis can be extended to other considerations, including the availability of generation units for local system demand and voltage stability.

Results from D-4's network analysis effort assist decision makers in the areas of policy analysis, investment and mitigation planning, education and training, vulnerability and criticality assessments, consequence management, and real-time crisis assistance.

Software Systems

The Software Systems Team, along with the Mathematical Modeling Team, recently started to develop the Interdependent Energy Infrastructure Simulation System (IEISS). IEISS simulates the physical and operational behavior of interdependent energy infrastructures during incidents and disruptions. It can identify and rank critical components across energy infrastructures, estimate outages, and quantify feedback

This tool's primary advantage is its ability to model the interdependencies between energy networks and to identify how a system's physical components behave during disturbances and contribute to their severity and measures the criticality of assets in a consistent manner across energy infrastructures. It also assesses potential feedback between energy transmission systems (cascading failures). It is possible to examine thousands of possible scenarios quickly to pinpoint what caused the most severe impacts. We can also determine the geographic extent of outages, including which customers are affected.

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D-5 Nuclear Design and Risk Analysis

The Nuclear Design and Risk Analysis Group, D-5, is a multidisciplinary team of scientists and engineers. We provide the modeling and analysis capabilities for designing and evaluating potential risks of complex systems, focusing on nuclear systems. D-5 goes beyond just providing answers: we provide answers in context to overall decision processes. We ensure that decision makers have all available knowledge to make an informed regulatory, design, or risk decision.

D-5 is a leader in the design of reactors for government applications, including space nuclear power. We are also a leader in the analysis of risk related to nuclear facilities, nuclear reactors, and nuclear weapons. D-5 employs a wide range of tools, including state-of-the-art radiation transport models, complex three-dimensional thermal-hydraulic models, combined experimental and modeling capabilities, and state-of-the-art logic modeling tools that encompass linguistic and numeric data. D-5 can provide answers to any questions involving nuclear systems.

D-5's core competencies include design and analysis of nuclear reactors; thermal hydraulics and computational fluid mechanics; application of radiation transport codes; probabilistic risk and safety assessments; probabilistic system and vulnerability modeling; facility safety analysis report development; nuclear weapons studies; explosive safety, logic-evolved decision trees and decision analysis; and custom software and engineering tool development.

FOCUS AREAS

Nuclear Safety and Regulatory Analyses

D-5 is supporting several Nuclear Regulatory Commission (NRC) directed research activities in the areas of safety performance and regulatory issues affecting the design and operation of nuclear power plants. Recent studies include a reliability assessment of an Emergency Core Cooling System (ECCS) during a Loss of Coolant Accident (LOCA) and a risk-informed regulation study to quantify the risk significance of nuclear power plant licensing amendments to improve operation and/or cut unnecessary costs. In addition, D-5 has helped the DTRA construct the world's largest plutonium storage facility (50 metric tons of plutonium) at the Russian Institute PO Mayak. D-5, which is the U.S. safety and design certification authority for this facility, ensured the design for DTRA in terms of security, materials control and accountability; safety of the storage of weapons-grade plutonium; and thermal performance of the facility.

Code Development

D-5 developed and maintains the Transient Reactor Analysis Code (TRAC). This powerful, system-level analytical tool has multiple applications to complex systems, including nuclear power plants, experimental facilities, and space reactors. TRAC also is a best-estimate tool to predict complex system response to off-normal events. D-5 is also assisting the NRC as it begins the licensing activities associated with new reactor designs and other advanced systems.

Risk-based Prioritization

D-5 uses risk-based prioritization tools such as human system optimization, application code development, logic models, and probabilistic modeling to assist with making informed decisions about risk issues and prioritizing resources. Even the most highly automated systems require human involvement, ranging from periodic supervisory assessment to emergency intervention to ultimate decision making based on system outputs.

Because information technologies increasingly comprise the key element of system functioning, the demands on human cognitive skills such as planning, maintaining situation awareness, and decision making with incomplete information are also increasing. A comprehensive understanding of human cognitive characteristics, e.g., requirements, tendencies, limitations, and the application of a decision-centered design approach, is therefore essential in development of efficient and effective information systems. Applying logic-evolved decision trees to vulnerability assessment and information loss has been one of D-5's growth areas. This methodology continues to find increased acceptance in the weapons community. The growth in the area of probabilistic system and vulnerability model is driven mostly by the events of September 11. D-5, together with Sandia National Laboratories, is performing vulnerability assessments for all operating civilian nuclear reactors.

Small Reactors

D-5's dedicated team of engineers is focused on developing space fission reactors. This team has developed several innovative reactor concepts, including a compact, robust, and safe reactor that is cooled by heat pipes. Several prototype units of the heat-pipe-cooled reactor have been built and tested successfully by D-5 and the National Aeronautics and Space Administration (NASA). NASA intends to use this reactor to enable ambitious, electrical power-rich exploration anywhere in our solar system.

Weapons Safety

D-5's work in the area of stockpile stewardship supports the Laboratory's mission to reduce the danger of nuclear mishaps. Our expertise in this area is focused on designing safety into nuclear weapons production and maintenance processes, conducting nuclear explosive risk and damage assessments, and evaluating the safety of testing programs related to nuclear weapons.

We also develop custom software for these assessments.

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D/DoD Department of Defense Program Office

The Department of Defense Program Office is part of the D Division organization and is responsible for the planning and Laboratory-wide integration of DoD non-nuclear weapons defense programs. The office strives to enhance the DoD programs portfolio through effective communications and interactions with DoD sponsors, opportunity assessments, program development, integrating Laboratory-wide efforts, contributing to strategic planning, aiding with Los Alamos proposal development, and supervising DoD programs execution. The DoD Program Office goal is to support the Laboratory, the Threat Reduction Directorate, and D Division strategic plans and to apply the Laboratory's expertise to the broad spectrum of military technological needs.

FOCUS AREAS

Conventional Weapons Technologies

The conventional weapons technologies area exploits and enhances the core strengths of the Laboratory in conventional munitions, high explosives and energetic materials, advanced warheads, and lethality and survivability. The Laboratory is developing new energetic materials that perform as well as today's best materials but have improved properties, including safety. As part of this work, Laboratory researchers are developing new models to predict quantitatively how explosives will behave in abnormal environments such as accidents or fires. The Laboratory is developing initiation systems based on exploding foil technologies to provide design flexibility, enhance weapons safety, and lower production costs. The Laboratory is also implementing major improvements in computer codes to simulate the behavior of weapons systems and subsystems. Researchers are investigating new, physics-based computations of material behavior to significantly improve our ability to predict explosives effects.

Defense Advanced Concepts

Defense advanced concepts programs are often relatively small efforts to develop or understand technologies and to focus them on specialized DoD applications. Optimally, a successful concept grows into a major program. These efforts tend to change from year to year. Presently, Los Alamos is developing high-power microwave technology with several potential applications. Laboratory scientists are also working on biomimetic computing and understanding eye-brain function These projects should lead to advanced detection systems that emulate how humans "see." The Laboratory is also working on concepts for detecting and even defeating enemy underground facilities.

Defense Sensor Technologies

Defense sensor technologies work is focused on developing sensors for treaty verification, space-based surveillance, satellite protection, and the battlefield. Los Alamos is supporting the Air Force in detecting nuclear explosions, primarily using detectors (W-sensors) integrated into Air Force satellites orbiting Earth. This support includes developing and maintaining specialized software and models for assessing radio sensor performance and radio signal propagation through Earth's ionosphere, on-orbit sensor testing, and systems and data analysis. These, and other, sensors are also used to study "space weather," allowing us to understand satellite performance and reliability. Los Alamos has also developed an ultrasonic device to nonintrusively detect chemicals in various containers such as artillery shells and 55-gallon drums for treaty verification and counterproliferation programs.

High-Performance Computing

The Laboratory's high-performance computing initiatives are developing a computing environment that solves large-scale, complex problems for both defense and dual-use applications. Los Alamos is working with IBM on a project to develop a new generation of high-performance computing. There is also a large effort to develop and use reconfigurable computers for intelligent sensors as well as for large "main frame" computation.

Modeling, Simulation, and Analysis Applications

DoD synthetic environments are virtual representations of the physical and behavioral phenomena of complex military systems that are achieved through mathematical modeling and simulation. These environments are used for training (eliminating the costs of thousands of troops, planes, and ships in the field) and for testing novel war fighting strategies and tactics against new threats or using new weapons and information. Los Alamos is working on tools for this training and analysis regime. There is also a need to simulate complex infrastructures, such as the entire power grid, to determine vulnerabilities or even efficient points of attack that could shut down enemy command and control. We have several projects in the area of understanding infrastructures. Additionally, using complex agent-based and statistical models, we can understand and predict some human behavior. Based on these concepts, Los Alamos developed a model and simulation of terrorist networks and how they might respond to different stresses.

Directed Energy

There are numerous needs within the DoD for directed-energy systems, ranging from man-portable to large missile systems. Los Alamos is currently working with the U.S. Navy on free-electron laser technology, for potential installation on warships. This technology has the potential to rapidly destroy attacking missiles. We are also working on concepts for making high-powered, directed microwave systems much smaller and more useful.

System Performance and Reliability

Major weapons systems, e.g., an entire new fighter jet, often cannot be tested or even designed without extreme costs or potential of destruction. Los Alamos is designing statistical tools to allow prediction of the overall system behavior using data from limited subsystem testing and from computational models. These statistical tools allow designers to understand failure points and then focus design efforts on these points. We are also developing hardware and software to predict the component failure. This allows repair or replacement of parts when they actually become worn rather than on a maintenance schedule. This vastly improves reliability as well as cutting costs.

Chemical, Nuclear, and Radiological Defense

Advanced technologies that provide defenses and responses to WMDs are a major focus area for DoD programs. Traditionally, the quartet of chemical-biological-nuclear-radiological threats defines WMDs. The chemical-nuclear-radiological systems characteristically have close technical ties to nuclear weapons and conventional munitions activities and are part of the DoD programs. The CHS handles biological threats. There are DoD programs to detect hidden nuclear devices and to understand the systems and requirements to position detectors for maximum efficiency. We are also starting a major program to develop technology and operational methods to decontaminate affected areas after a radiological attack.

Missile Defense

The DoD has identified missile defense as a major element in the ongoing force transition ordered in response to changes in the international threat since the end of the Cold War. These changes predicate a need for a more dispersed and faster responding defense net. Our DoD missile defense projects are providing the research and development for advanced missile defense systems that will meet the challenging performance requirements inherent in responding to increased global threats.

Military Space Applications

Los Alamos' history of developing and building small satellites and instruments for satellites puts us in position to aid in many military problems in space. Current research includes developing sensors and data analysis to give real-time, battle theater information and systems to measure and understand threats to the United States' complex, existing satellite network.

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Decision Applications Division

Research Summaries

Information Integration Technology

In many disciplines, integration of scientific theory and analysis with experimental data, modeling results, and other types of information occurs through some test event or in the mind of a scientist or decision maker. The goal of information integration technology (IIT) is to develop methods for combining and integrating information from diverse sources to produce a traceable, mathematically rigorous assessment of system performance.

For example, to help understand reliability of a complex system, members of D-1's System Ethnography and Qualitative Modeling Team work with statisticians and customers to develop analytical models that allow us to combine system and component reliability estimates and to analyze diverse data sources, including expert judgment, in a way that clients understand.

We have developed a framework of processes and tools to automate much of the modeling effort. The framework is flexible enough so that we can make use of information from a variety of sources, including theoretical models, test data, computer simulations, expertise, and expert judgment. It merges techniques from statistics and probability, graph theory, knowledge acquisition and representation, computer science and simulation, and decision theory. IIT integrates these diverse sources of information and associated uncertainties to develop full distributions for performance metrics that can aid decision making under uncertainty.

We are applying IIT in collaboration with partners from the weapons community here at the Laboratory, from industry, and from the DoD. For example, in conjunction with the Missile Defense Agency, we developed a predictive reliability model for an upcoming flight.

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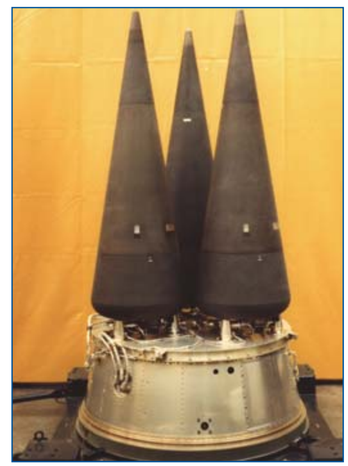

Information Integration Technology (IIT) has a wide spectrum of application areas, from improving the reliability of production processes for diapers to predicting performance of weapons systems.

Genetic Data Analysis

Our genetic data analysis research involves management and analysis of information about biological systems. An example is Amplified Fragment Length Polymorphisms (AFLP) Analysis. Given an inventory of fragments of given lengths, because of a specific cutting routine, it is possible to make comparisons through "fingerprints," that is, reduced parameter data sets specific to each organism.

In collaboration with scientists from B Division, we create models of the data, and then perform a statistical/computer-based analysis of AFLP data. This analysis allows us to identify and classify biological organisms of interest with regard to national security issues.

AFLP analysis has been used to classify and identify certain organisms that have been in the news recently, including strains of *Bacillus anthracis* (the bacterium that causes anthrax). Other issues we are addressing include using replicates (they are sometimes not used because of excessive analysis time), the incorporation of uncertainty in comparisons/decisions, and data integration (e.g., how to combine information from controlled experiments with "real world" data from the field, perhaps from intelligence sources).

Applications include rapid identification of organisms and pathogens, identification of geographic soil locations, classification of ecological microclimates, development of "background" soil and air microorganism content, and early warning systems/surveillance for biological threat agents.

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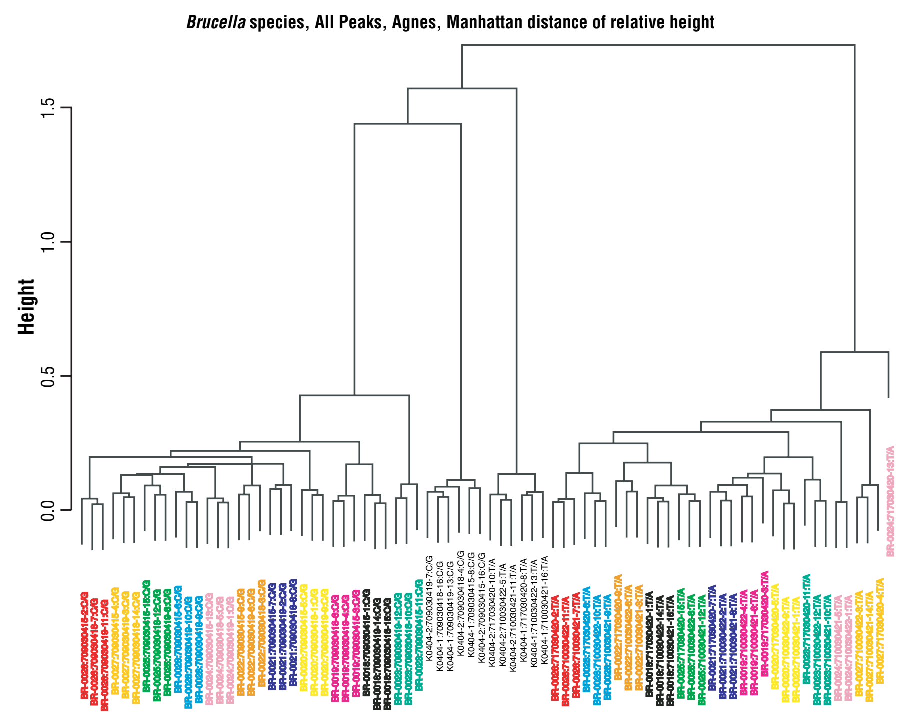

Comparison of replicates from two different amplified fragment-length polymorphism (AFLP) primer pair profiles. The clustering of the replicates shows that these data analysis techniques for AFLP profiles might be used to identify unknowns.

Computational Statistics

YADAS, (the shorthand name of the Yet Another Data Analysis System) is a software system written in Java for MCMC analysis of statistical models. It is intended to be extensible to handle new models that researchers devise and to make it easy to implement these models. It emphasizes the use of Metropolis steps, relieving the user of the responsibility of calculating full conditional distributions. YADAS contains a versatile library for expressing relationships between parameters, as well as a library for proposing parameter updates that improve the mixing properties of the chain.

YADAS has several features that will appeal to statistical researchers. It enables the specification of most models without writing a great deal of new code and allows users to update the parameters in their MCMC algorithms in arbitrary ways. It also offers an easy method to propose Metropolis-Hastings moves in arbitrary directions and powerful and intuitive ways to improve convergence of difficult MCMC algorithms.

The source code for YADAS is openly available, and researchers are encouraged to modify it for their own use. The program is receiving widespread use within D-1 and has been acknowledged as pivotal in solving several very time-consuming problems

.

D-1 statisticians, in collaboration with weapons scientists at the Laboratory, have used YADAS to analyze and estimate the reliability of stockpile components. It has also been used to model and analyze performance of a complex system for with a mixture of information, some at the system level, some at component level, and some at subcomponent level. YADAS is especially well-suited for analysis of such types of hierarchical models.

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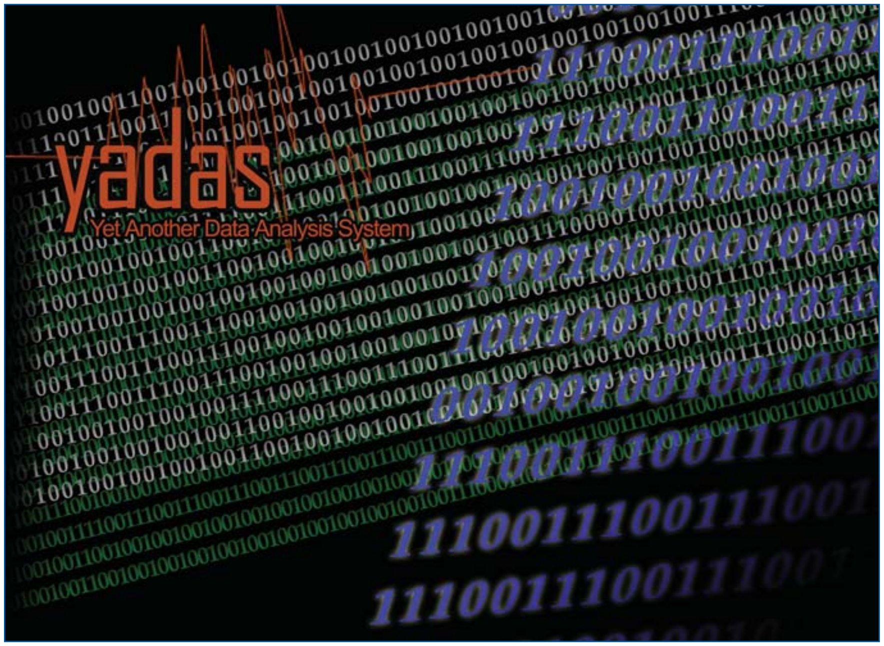

YADAS contains a versatile library for expressing relationships between parameters, as well as a library for proposing parameter updates that improve the mixing properties of the chain.

Uncertainty Quantification

The Laboratory's certification efforts supported by developing methodologies to quantify the uncertainty in all aspects of performance of the stockpile. We provide this support through modeling and statistical analysis of physical data, and also through computer model evaluation.

With computer models, we are concerned with how far apart the real outcome and predicted outcome are likely to be at a specific prediction point in light of evidence at other, specific data points. The real and predicted outcomes can be expected to differ for several reasons, e.g., uncertainty resulting from model specification (it may be too far removed from reality) or inputs (data used may not adequately characterize actual conditions in the physical world).

D-1 is collaborating with weapon physicists on several efforts to integrate and utilize all available information and relevant data in environments where data is sparse, expensive, and, in some cases, impossible to obtain. Methods developed and applied on these projects include Bayesian (data combining) methods, analysis of expert judgment, linear and nonlinear modeling, multivariate analysis, and analysis of variance components.

We have applied these methods and tools to help answer questions in a variety of areas, from sampling issues that arise in core surveillance to resolution of significant findings.

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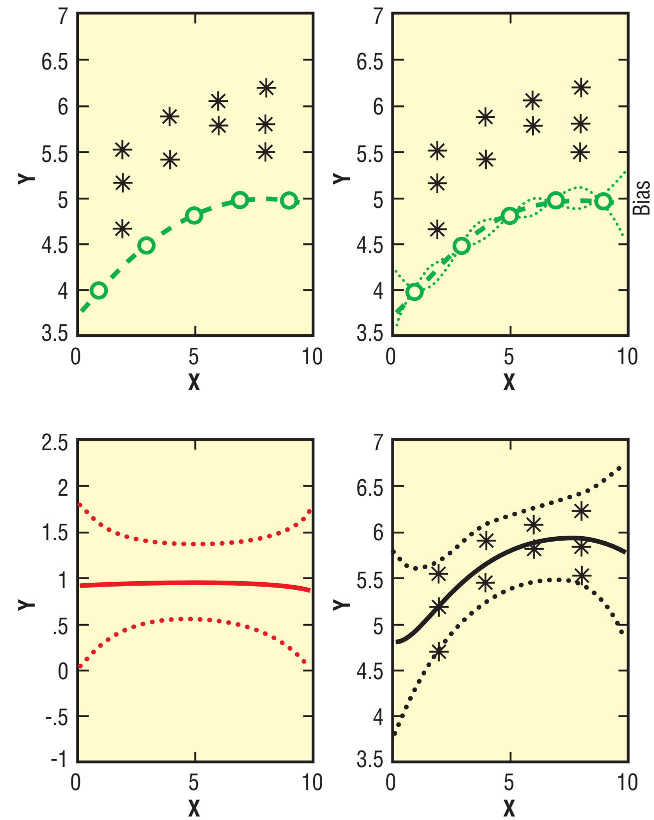

(Upper left) Observed field data (black circles) and simulation output (green dots) taken at various configurations x. (Upper right) An interpolative model for the simulator is constructed to estimate simulation output at untried values of x, along with its uncertainty. (Lower left) Estimated discrepancy term and its uncertainty. (Lower right) Predictions for new observations are given by the sum of the simulator and the discrepancy.

Improving the Reliability of Large-Scale Industrial Manufacturing Processes

In collaboration with Procter & Gamble (P&G), D-1 staff members have developed a statistical model to evaluate the reliability/availability of alternative process configurations. PowerFactoRE is a suite of reliability engineering tools for optimizing the manufacturing process. It is a comprehensive methodology and an integrated suite of reliability engineering tools that introduces a new way of thinking about the manufacturing process. PowerFactoRE received an R&D 100 Award in 2003. The model is developed in such a way that a genetic algorithm can be used to identify those processes having high reliability/availability.

PowerFactoRE comprises a unique set of proven methods, statistical and analytical tools, simulation software, procedures, and training that enables manufacturing line managers to understand reliability losses and to correct seemingly isolated defects in the manufacturing process. It gathers and analyzes production data; fits the data with accurate statistical distributions to build a simulation of the system; and validates the system model.

It allows a manufacturer to improve the current system or to evaluate a completely new configuration.

This methodology can be applied across a wide range of businesses to increase productivity and production and to guide capital investments. It is currently being used in more than 200 plants worldwide, and P&G has saved over one billion dollars since implementing PowerFactoRE.

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PowerFactoRE is a unique set of tools that assists manufacturing line managers in assessing reliability losses and in correcting isolated defects. It earned a 2003 R&D 100 Award.

Statistical Population Bounding

Often, we are not interested in confidence intervals on means, but in bounds on quantiles of distributions. The basic population bounding problem is to determine bounds that contain a desired fraction of the population. In other words, whereas confidence limits bound the mean with a specified level of confidence, and prediction limits bound individual predicted points, tolerance bounds contain a specified proportion of a population with a desired confidence. Collaborating with physical scientists, we create statistical models to study the behavior of material characteristics.

In extensions from the basic problem, we consider distributions as they age over time, multiple populations, assessment of measurement processes, and bounds on probabilities.

Using these techniques, we have studied the behavior of plutonium over time by designing and analyzing experiments to collect measurements of samples of aged plutonium. We have also modeled and provided uncertainty bounds for age-related material characteristics (such as molecular weight) of the polymer binder in high explosives.

Other application areas include analysis of historical data on engineering components to predict and bound behavior of components over time; evaluating the reliability of canisters for use in long-term storage of radioactive waste with particular interest in degradation associated with internal pressure buildup with time; analysis of glove box failure data to understand glove deterioration and age-related failures; and models to understand environmental exposure, material properties, measurement and production system variation, and nondestructive measurement techniques.

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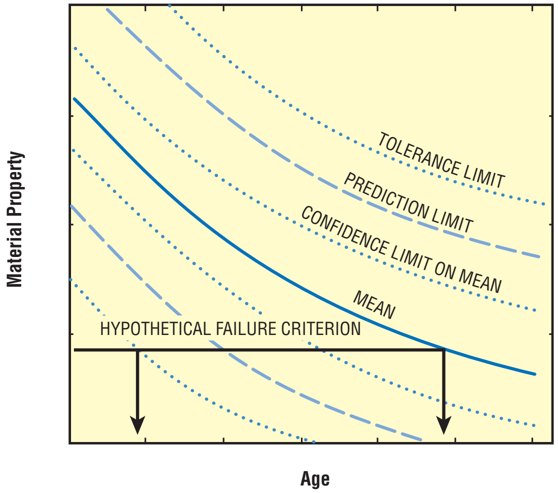
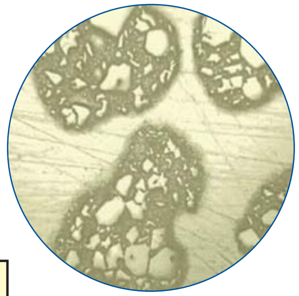
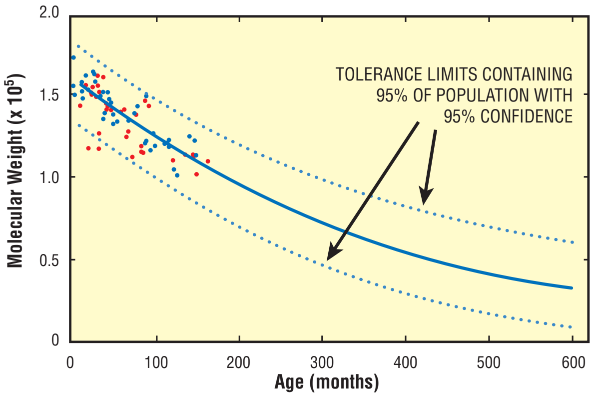






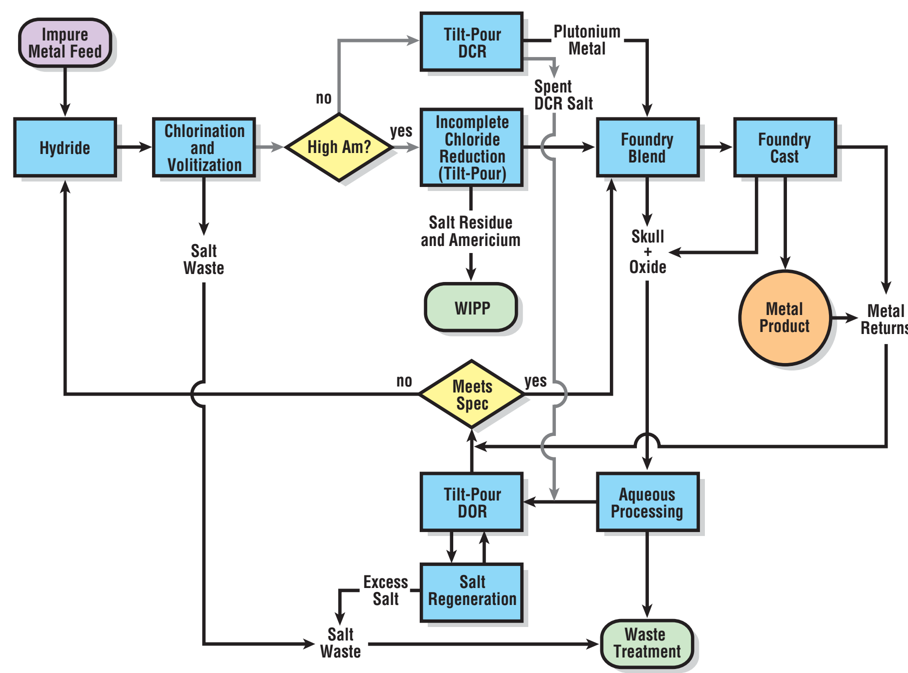
Tolerance limits, prediction limits, and confidence limits, displayed in the upper schematic figure, illustrate three different types of statistical bounds. Molecular weight was measured for several samples of a polymer material, shown on the right at high magnification. Computational resampling was used to develop tolerance limits, displayed in the lower figure, on the molecular weight of the polymer.

Modern Pit Facility Manufacturing Systems Modeling and Analysis

This Modern Pit Facility (MPF) Manufacturing Systems Modeling & Analysis project uses a combination of modeling, simulation and, analytical tools to perform a systematic, detailed analysis of several types of manufacturing systems including factories, recovery/refining operations, and assembly operations. The project first deploys a data acquisition team to obtain detailed operational, layout, and unit process information. This part of the analysis is usually the most valuable to anyone interested is determining how a manufacturing system is functioning in terms of efficiency, resource utilization, and management capability.

The information gleaned from the data acquisition process is then incorporated into a system modeling/simulation tool called ProMoS, and the team runs the simulation to determine obvious bottlenecks and other nascent system features and to validate the tool and data. Necessary adjustments are made to the tool and the team submits any requests for additional data. Both the modifications to the database and/or tool configuration and the additional data requests represent the second most important aspect of the entire process. After completing the modifications and incorporating the additional data, the team runs the simulations again for data verification and to determine the completeness of the database and manufacturing features of the system under investigation. This modification/database-refinement process is repeated until we attain the level of precision necessary to complete the systems analysis to the satisfaction of the customer.

Once the model is appropriately modified and the data is refined, the model performs the required simulations for record to establish the baseline. A baseline is established and validated, then the model is run in a variety of customer/client-provided scenarios to provide an operating envelope for the manufacturing system under study. The team uses Access, Excel, and PROOF (a visualization tool) to create a detailed analysis of these scenarios and to provide data-rich numerical and graphical representations of overall system performance under the scenario conditions. As a result, a factory can be operated virtually to determine if green-field new-builds, modifications, expansions, or transformations can be economically or efficiently completed and operated as designed. Additionally, the analysis may be performed to “optimize” an existing system to increase resource utilization or maximize profit.



Metal preparation/purification flowsheet for the Modern Pit Facility (MPF).

The team conducts a model-based analysis of complex manufacturing systems—in particular, small-lot manufacturing of high-reliability components or assemblies. The results of the analyses are used to complete simulations of factory performance during the design phase to reduce design and build costs and to increase factory productivity and robustness. A factory can be designed to operate in any specified optimal mode.

We developed models that provide comparisons between the different technologies for the MPF program and to establish data to guide technology development. The potential impact of a given technology can be tested in the manufacturing environment (assuming best estimated performance criteria) to determine the productivity, cost, or safety performance of the modeled technology. This approach determines which projects have high-impact potential and directs the technology development resources to those projects.

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Pit Manufacturing Capability Program

Under the direction of the NNSA the DOE laboratories and operations sites are re-establishing pit manufacturing capability to assure United States' readiness to manufacture war reserve pits. D-2 manages the LANL Pit Manufacturing Capability Program. In addition to the W88 Manufacturing and Certification Program at the Laboratory, the Pit Manufacturing Capability Program will reacquire and maintain a modern capability to manufacture all pits within the enduring stockpile while supporting other NNSA programs.

Updated manufacturing processes are a critical factor in assuring U.S. readiness and capability to manufacture pits. This team identifies, develops, and deploys new technologies that provide the robust, flexible, cost-effective pit manufacturing capabilities needed to sustain U.S. pit manufacturing capabilities. The manufacturing process will span many decades and is expected to encounter numerous changes in requirements and available technologies during that time. The team continually looks forward to emerging technologies, assesses them, and selects specific technologies for proof of concept and continued development.

Integrated technology planning, decision making, and management are generally applied when several interrelated technologies are going to be combined into systems where both requirements-driven technology development and optimization analysis are important.

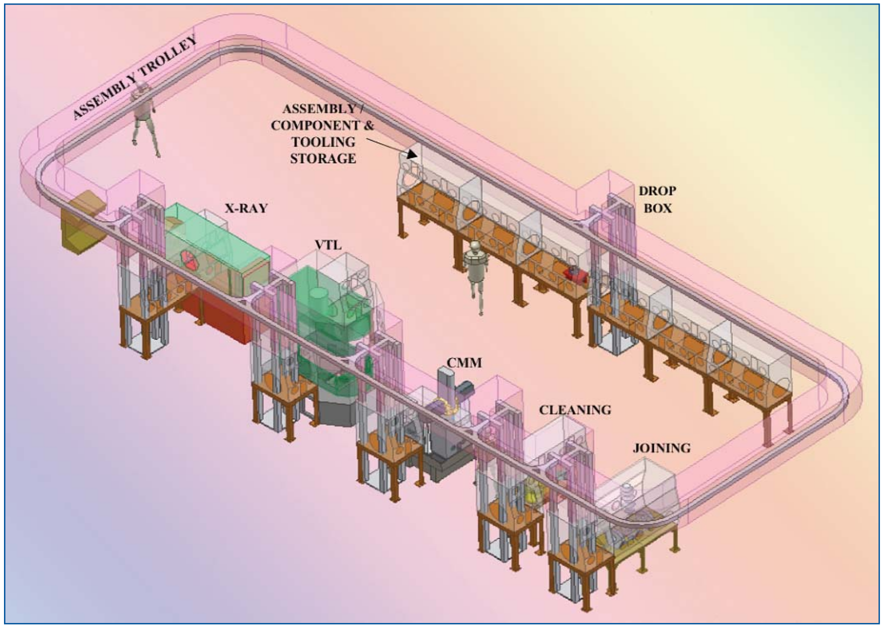
The team has realized several recent accomplishments:

In conjunction with NNSA and the DOE laboratories and sites, they completed a technology integration strategy that defines a national approach to pit technology development.

They organized and now lead the Process Technology Development Board that integrates Laboratory weapons manufacturing process development. They established an optimized manufacturing baseline and defined the process priorities and competing technologies.

Additionally, they completed the Pit Manufacturing Technology Implementation Integrated Plan for NNSA that integrates the complex-wide development program and initiated and procured equipment for the Laboratory's technology development efforts that support pit manufacturing.

The team collaborates with colleagues at NNSA, Lawrence Livermore National Laboratory, Sandia National Laboratory, Savannah River Site, Kansas City Site, Y12 Site, and Laboratory divisions D, NMT, ESA, X, and MST.



Proposed advanced pit fabrication model.

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Complex Manufacturing Systems Modeling and Analysis

The Complex Manufacturing Systems Modeling and Analysis project uses a combination of modeling, simulation, and analysis tools to perform a systematic, detailed analysis of manufacturing systems. It first deploys a data acquisition team to obtain detailed operational, layout and unit process information. The information is then incorporated into the ProMoS simulation tool, and the system is then simulated to determine obvious bottlenecks and other nascent system features to validate the tool and data. Adjustments are then made to the data base and/or tool configuration and the simulation is then run for record.

Once a baseline is established and validated, the model is run in a variety of customer/client provided scenarios to provide an operating envelope for the manufacturing system under study. The detailed analyses of these scenarios are performed using Access, Excel, and PROOF to provide data-rich numerical and graphical representations of overall system performance under the scenario conditions. As a result, the factory can be operated virtually to determine if green-field new-builds, modifications, expansions, or transformations can be economically or efficiently completed and operated as designed.

The team conducts model-based analysis of complex manufacturing systems, in particular, small-lot manufacturing of high-reliability components or assemblies. The team used the completed factory performance simulations during the design phase to reduce design and build costs and to increase factory productivity and robustness. A factory can be designed to operate in any specified optimal mode.

Models were developed that provide information for the MPF program and establish data to guide technology development. The potential impact of a given technology can be tested in the manufacturing environment (assuming best estimated performance criteria) to determine the productivity, cost, or safety performance of the modeled technology. The results can be used to determine the projects with high-impact potential and then direct technology development resources towards those particular projects.

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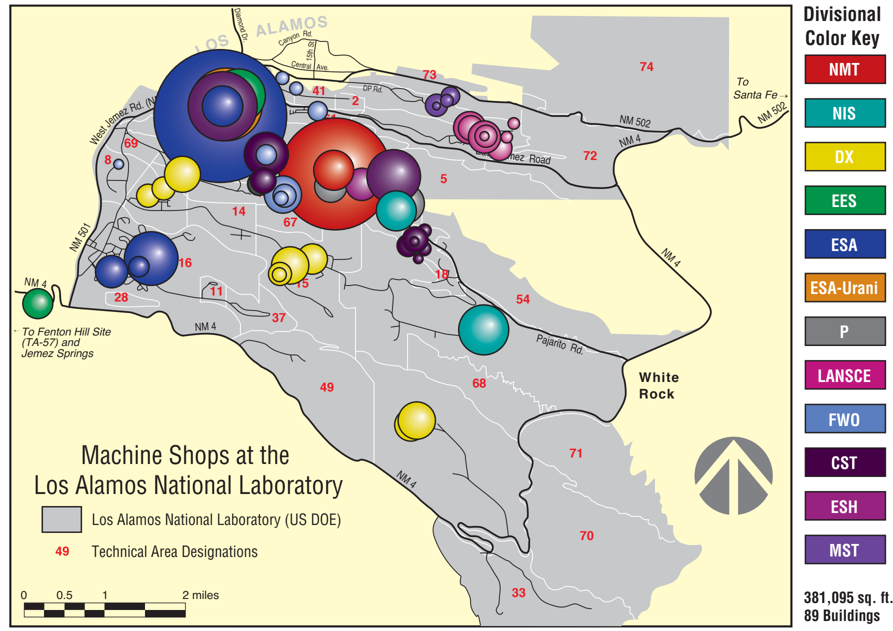


Model-based analysis of complex manufacturing systems, including processes at various locations, helps optimize manufacturing processes.

Nuclear Planning and Analysis

Integrated Nuclear Planning (INP) is a concept born in part out of the Chemistry Metallurgy Research (CMR) Upgrades Project and in support of the CMR Replacement Project. Several projects at Los Alamos will be working in the Pajarito corridor to provide or support nuclear materials operations. These projects will benefit considerably from an integrated site-wide planning approach that transcends independent organizations and programs.

Integrated planning should minimize gaps and overlaps of capabilities between various projects and provide a cost-efficient framework for addressing infrastructure needs, including office space, cold work space, security, roads and parking lots, and utilities. The focus of integrated nuclear planning is to initiate workshops that bring Laboratory and DOE personnel together to address issues and establish consensus/consent on those issues, and to direct Laboratory personnel regarding further studies, such as establishing mission requirements, responding to required action elements, prioritizing elements for implementation, and defining individual project scope and schedule.

Integrated Nuclear Planning is generally applied when several interrelated projects are going to be executed, such that interference and optimization analyses are important.

The INP team has organized and led six joint DOE/Los Alamos workshops to date:

Workshop 1 was held at DOE/AL on April 18, 2001. The focus was on establishing the Laboratory-supported plutonium-related mission set for the foreseeable future.

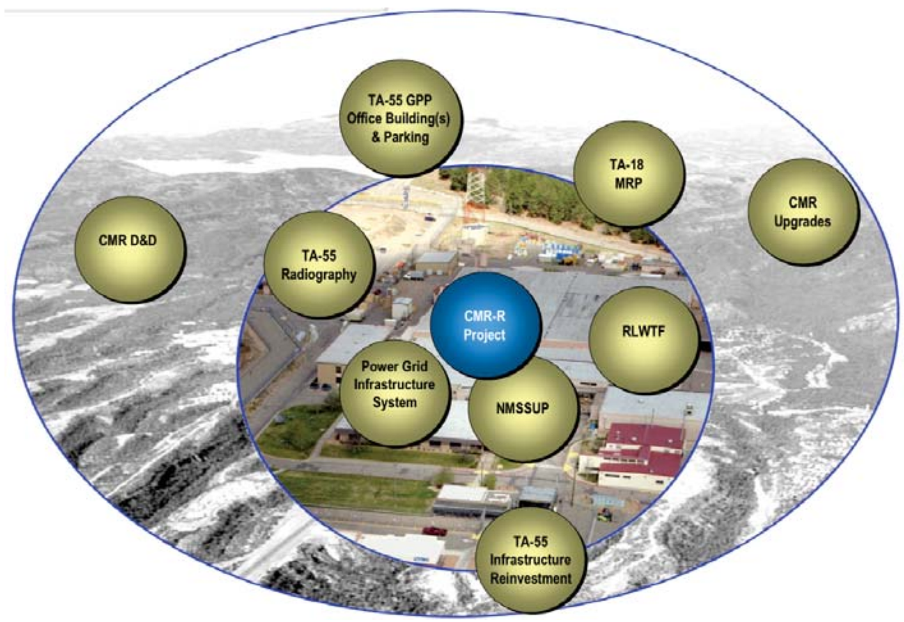
Workshop 2 was held at DOE/Albuquerque (AL) on July 10–11, 2001. The focus of the first day was the TA-18 Relocation Project. The second day focused on establishing the operations to be housed in CMRR and a first estimate of space requirements.

Workshop 3 was held at DOE/AL July 23–24, 2002. This workshop included a variety of topics including the CMRR, TA-55 facility issues, radioactive liquid waste treatment facility (RLWTF), and Los Alamos space consolidation efforts.

Workshop 4 was held at DOE/HQ October 8, 2002. The focus was a revalidation of the mission set and customer base for TA-18 operations.

Workshop 5 was held at DOE/AL June 9–10, 2003. The focus was on the selection of the preliminary CMRR layout and options revalidation.

Workshop 6 was held at DOE/AL on August 19–20, 2003. The focus was INP-related project interface issues and the status of the working teams looking at safeguards and security, large vessels, and storage.



A conceptual view of the projects to be focused on by the Integrated Nuclear Planning team. Currently, the central project is the CMR Replacement Project.

The next workshop is being planned for Spring 2004.

Collaborators on this project are DOE, the Laboratory's C, NMT, S, PM, and NIS Divisions, and the ADO office.

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Biological Countermeasures Programs

BASIS provides early warning of airborne biological weapons attacks. Planned for use in civilian settings, BASIS can detect a biological attack within a few hours, early enough to treat exposed victims and limit casualties significantly.

The Biological Aerosol Sentry and Information System (BASIS) program has developed integrated systems for countering aerosolized bioterrorist releases. Our detect-to-treat technology includes air-sampling hardware, controlling software, and high-confidence DNA-based analysis to rapidly detect, time-and-place pinpoint, and species/strain-characterize aerosolized bioagents.

The visible “front end” component of BASIS is a network of strategically deployed air samplers in and around cities, airline terminals, bridges, etc. Software for this program has been developed to keep tabs on air-sampling operations. BASIS operators must adjust the air samplers’ parameters from time to time, so each sampler communicates with the operator by laptop computers running the BASIS Command and Control software, through coaxial cable, radio frequency, or cellular modem. The software allows the operators to remotely monitor and adjust all critical parameters for the samplers. For rapid recognition, these parameters are displayed both numerically and graphically. The BASIS architecture was adapted in early 2002 to support the nationwide deployment of BioWatch, a DHS-sponsored program to detect a bioaerosol release in many U.S. cities.

The Incident Characterization Action Plan (ICAP) is an effort to develop a template for the early stages of the consequence management operation that would be initiated by indications from BioWatch that a bioterrorism incident may have occurred. Specifically, it focuses on operations during the first few days after a positive detection, when it will be essential to characterize the event as quickly and completely as possible. The deliverable of this effort will be a “template” that will be provided to all BioWatch cities.

The BioNet program is a cooperative program between the DHS and the DTRA. This program will integrate both civilian and military capabilities for detecting and managing the consequences of biological events, including bioterrorist attacks. BioNet will leverage DTRA and DHS consequence management capabilities to support DHS’s science and technology objectives and DTRA’s mission. We will also optimize systems and concepts of operations (ConOps), develop consequence management tools and ConOps, operationally evaluate the next generation of aerosol monitoring technologies, expand high-throughput sample processing capabilities, and develop system optimization models.

The BASIS and BioWatch systems are designed for indoor or outdoor deployment in any situation in with a probability or an actual threat of a bioterrorist attack. Currently, the ongoing BioWatch deployment protects a significant number of major American cities, using simplified versions of the BASIS distributed sampling units, deployed in concert with local air quality sampling activities and analyzing filters through laboratories that are part of the Centers for Disease Control and Prevention’s (CDC) Laboratory Response Network. The deployment is designed to guard against large-scale urban attacks. By deploying a smaller, more-portable air sampler and using the testing laboratories affiliated with the CDC to perform DNA-based analysis, the DHS has quickly pressed the BASIS technology into service. The BASIS team continues its research and development work, seeking to improve all aspects of system performance.

An ICAP manual will be developed to assist the BioWatch cities in establishing a situational awareness team that will direct and implement the ICAP template. This manual will include recommendations regarding actions and time lines, needed information products, available tools and resources, notifications and communications, and membership.

There are significant variations in the emergency response structures and approaches in the BioWatch cities. The ICAP manual will serve as a "starting point" for the development of specific plans suitable for the unique characteristics of an individual locality. In addition to providing guidance to state and local agencies for their own operations, it will specify how these can mesh with federal response operations under the National Incident Management System (NIMS), especially those that are controlled by DHS.

The BASIS team earned an R&D 100 Award in 2003. This program also received a Laboratory large-team Distinguished Performance Award. In 2002, BASIS was deployed at the Winter Olympics in Salt Lake City and in New York City for the anniversary commemoration of September 11th.

D-3 collaborates with Lawrence Livermore National Laboratory, Rupperecht and Patashnick Co. Inc., the U.S. Environmental Protection Agency, the Centers for Disease Control and Prevention, local air quality agencies, and the Laboratory's P-24, ISR-4, and S-10 groups in these efforts.

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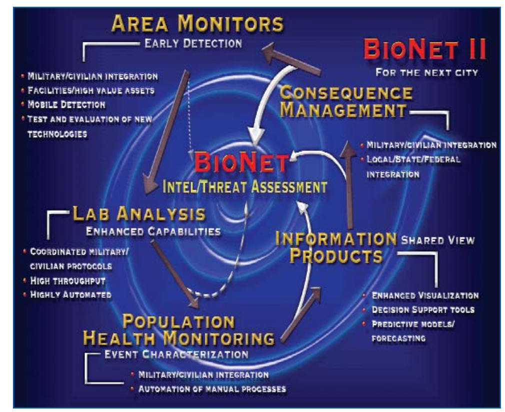
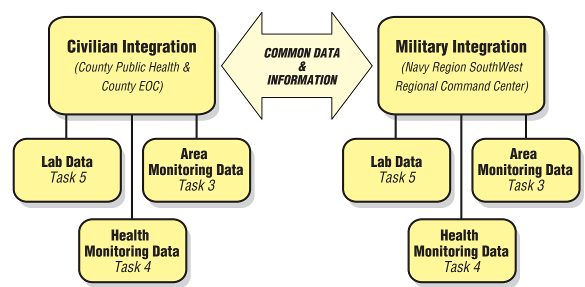


(Upper) Screen shot of BASIS operations console. (Middle) BioNet flow chart. (Lower) The primary goal of BioNet is to make the civilian (BioWatch) and the military (Guardian) programs interoperable.



Maritime Study

The Maritime Surveillance System Study is a systems-based assessment of alternative technologies and surveillance strategies to detect nuclear weapons smuggling, radiological dispersion devices (rdds), and special nuclear materials in shipping containers. It addresses the smuggling opportunities afforded by the seven million intentionally opaque containers imported through U.S. ports annually that are a potential threat to homeland security.

The study consists of six major elements: (1) a physics-and engineering-based assessment of the available and near-term sensor technologies for detecting nuclear materials hidden in shipping containers, (2) an economic analysis of the impact of surveillance operations on the maritime transportation system, (3) an assessment of the available data on the maritime shipping system, collecting data, and maintaining a database, (4) a high-fidelity simulation of shipping terminal operations, (5) a systems model that evaluates surveillance strategies, and (6) an analytic effort to create, compare, and optimize alternative surveillance strategies.

In addition to the direct application of detecting nuclear weapons, rdds, and nuclear materials in shipping containers, the study developed an approach, methodology, architecture, and tool-set for use in other surveillance applications. The analysis extends directly to rail, road, and airfreight imports. The study methodology also would apply to other targets, such as biological, chemical, or conventional weaponry, if the appropriate sensor technologies can be identified and assessed.

The study has produced a comprehensive assessment of passive radiation sensor technology, radiographic imaging technology, and active irradiation technologies for detecting concealed actinides and other radioisotopes. In addition, the study has developed a methodology to assess the performance of information-based methods (e.g., shipping manifest assessment). A high-fidelity, agent-based simulation of a representative shipping terminal has been implemented and validated and is used to perform million-container numerical experiments to examine the impact of surveillance operations on the terminal. The assemblage of data from many diverse aspects of the maritime transportation system is a unique asset. We have developed a conceptually simple yet powerful architecture for representing surveillance systems with multiple sensor types in a way that allows comparison and optimization of surveillance strategies.

The study has participants from throughout D Division and the Laboratory's P and N Divisions. Outside the Lab,

D Division is actively involved in a maritime surveillance study that analyzes potential vulnerabilities of commercial shipping. With the system shown in the upper photo, a large U-shaped structure with a linear accelerator on one side and x-ray detectors on the other can be driven over a cargo container to produce an x-ray image. The resulting image shows neutron emissions, which are a signature of nuclear material.

contributors to the study include U.S. Customs and Border Protection Agency (both operations and intelligence), U.S. Coast Guard, the U.S. Merchant Marine Academy, Lawrence Livermore National Laboratory, Sandia National Laboratory, Pacific Northwest National Laboratory, The Yusen Terminals, Inc. terminal at the Port of Los Angeles, the Maryland Port Authority, the University of Maryland, and the University of Michigan.

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Unconventional Nuclear Warfare Defense

This Unconventional Nuclear Warfare Defense (UNWD) program involves the integration of a number of unattended sensors and cameras with communication links and displays for potential use in detecting unauthorized movement of radioactive materials. It also includes sensor testing, communication network design, data format development, and installation and implementation issues. The UNWD program is a collaborative effort of multiple contractors, government agencies, and national laboratories.

The purpose of this project is to demonstrate the capability for real-time detection and notification of unauthorized radioactive material movement. The system uses a variety of commercially available sensors. The project includes establishing an outdoor test bed for side-by-side testing of radiation sensors with a variety of sources; selecting and installing sensors in a number of outdoor locations; developing a common sensor event reporting format for all sensors; linking the sensors to a central reporting station using a combination of radio frequency (RF), fiber-optic, and copper wire communications links; and selecting cameras and lighting to provide still images and live video of any event triggering any of the sensors. The sensor data and alarm reporting are displayed in real-time in the command center, resulting in immediate notification of response forces and are logged for further analysis. Representative systems have been installed in several operational facilities.

The team used quickly deployable, existing technology from both commercial and government resources to provide detection and reporting capabilities for civilian and military applications, including personnel and vehicle-entry control points to protected facilities. The equipment provides detection and alerting capabilities to on- and off-site security forces and should be employed in concert with existing security policies, procedures, and equipment.

Over the duration of the project, the system design has evolved to include nuclear radiation detection elements, distributed data communications, unambiguous alerting, provisions for both primary (gross) and secondary (detailed) inspection procedures and equipment, documentation of suspect activities (both visual and radiological), provisions for deployment in high- and low-traffic situations, and multilevel monitoring capability. The system includes data and video transmission through hardwire and non-hardwire RF communication.

The system is designed to allow existing security forces to detect, assess (with video snapshots of vehicles), and potentially track unconventional nuclear weapons, not to replace personnel. Generally, the deployment of this system does not generate additional security forces posts, but acts as a force multiplier by optimizing security forces employment and capability. The system can help the security forces commander to focus forces for the interception and engagement of an unconventional nuclear weapon threat and reduce or eliminate the need to disperse security forces in a detection role. We have installed, tested, and demonstrated the system at four military installations in the U.S., and we are continuing to monitor at some installations.

Lawrence Livermore National Laboratory, Sandia National Laboratory, Northrup Grumman, ARA, U.S. Army, U.S. Navy, U.S. Air Force, U.S. Marines, and DTRA collaborated with the D-3 team on this project.

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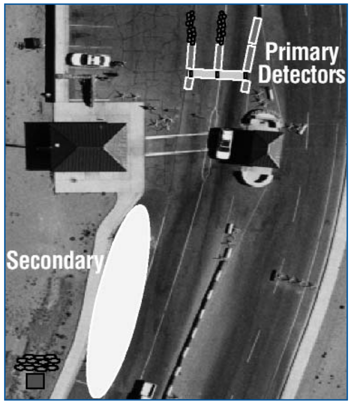


Portal monitors such as those shown above are specialized radiation sensors that are optimized for detecting radiation from nuclear materials at pedestrian or vehicle choke points. Lower photo is an overhead view.

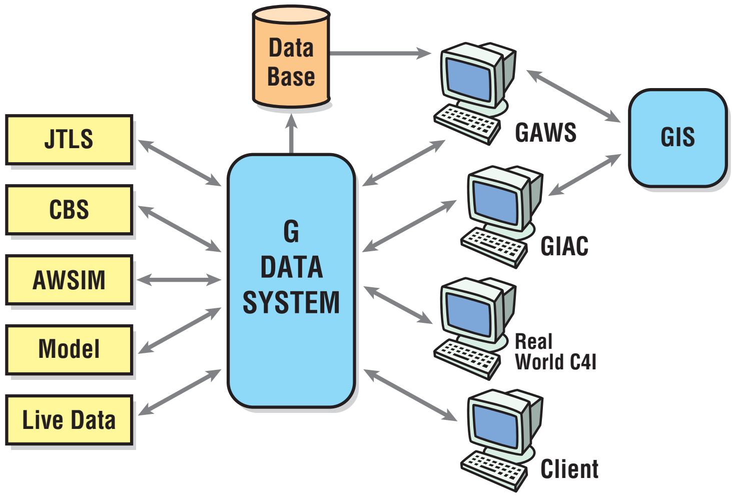
Graphical Integrated Aggregated Control (GIAC) Program

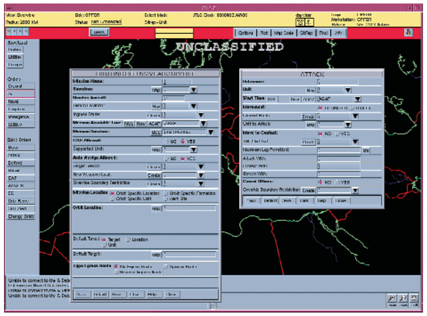
The Graphical Integrated Aggregated Control (GIAC) Program is a perfect example of computer graphics, distributed computing, system configurations and software engineering being used in one complete project. GIAC is a software system comprising two components: a graphical user interface (GUI) and Genis Data System (GDS), a distributed data system.

GIAC has over 500,000 lines of custom C and X-Motif code. GIAC's main function is to use computer graphics to display an electronic battlefield generation, training simulations, and war games, as well as provide input for simulation objects in a distributed environment—and do it fast (real time, or preferably a 4:1 ratio). GIAC also provides terrain analysis and features including line-of-sight (LOS) calculations, shaded relief mapping, radar echo analysis, terrain profiling, and National Imagery and Mapping Agency (NIMA) image map displays. LOS calculations are done in a distributed manner. GDS allows exercises to be configured over a LAN, or WAN, locally or worldwide. Distribution is accomplished with network programming using a socket application programming interface (api) written by GIAC team members in a point-to-point scheme (TCP/IP). Both software components are a complex code using well-known and custom-written, modified algorithms, and data structures to obtain the maximum performance and scalability/flexibility possible. GIAC is able to handle the distribution and interactions of over 100,000 simulation objects. The software can function on multiple hardware platforms, including HP, SPARC, and Intel, under those systems' native operating system, as well as Linux.

Every Military Simulation Center in the U.S. and NATO could use GIAC. The GIAC software is used around the clock for valuable training and mission rehearsals and was used to help plan the Kosovo air campaign. Major uses during the past year have been for homeland defense, the Millennium Challenge 02 Experiment, the Air Force's Distributed Mission Training, and many Joint Task Force-level training exercises.

Specifically for Millennium Challenge 02 (MC02), GIAC was modified to show all the model entities in the MC02 Federation minus single infantrymen in a White Cell (ground truth) mode. GIAC was also used as a debugging tool for the federation. GIAC was the main command and control (C2) control for air warfare simulation (AWSIM) object in both perceived and ground truth modes. GIAC allowed AWSIM operators to target federation objects and provided a mission history for mission reports (MISREPS) and battle damage assessment (BDA) reports.





(Above) Graphical Integrated Aggregated Control (GIAC) High-Level Architecture. (Left) Screen view of the graphical interface during one of the operational games.

GIAC performed flawlessly while supporting "white team" (ground truth) operations during Millennium Challenge 2002, the largest military experiment in history. The team also received a LANL Distinguished Performance Award for small teams in 2001.

We collaborated with U.S. Joint Forces Command, U.S. Air Force, Warrior Preparation Center, Raytheon, and the Laboratory's ISR-9 group on the GIAC project.

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Institutional Economic Analysis

Los Alamos National Laboratory is a large institution that plays an extremely important role in the economic and political life of northern New Mexico and the entire state. The Laboratory continuously encounters opportunities, choices, and alternatives related to this role. Laboratory management requires decision support and analyses to help select among alternatives, examine the consequences and implications of decisions and activities, and generally to sort good ideas from not-so-desirable ones.

Many institutions the size of the Laboratory have a corporate economics department reporting to high-level management in the organization, frequently to the president or director. Although the Laboratory does not have such an organization, D-4 personnel provide the Laboratory's equivalent of corporate economics information to the Director's Office.

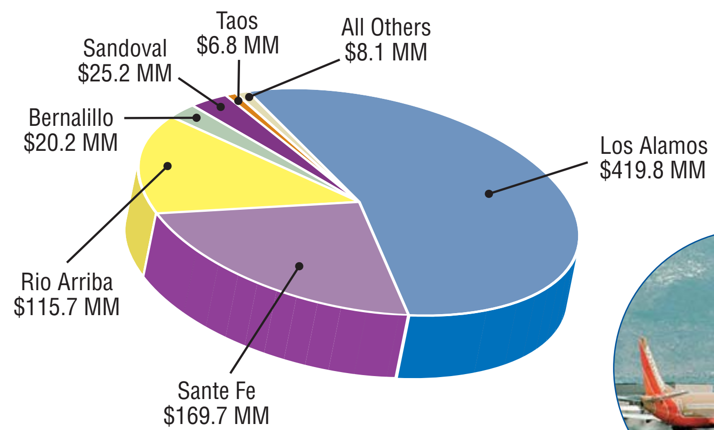
This work involves D-4 teams in a wide variety of decisions and analyses relating to the Laboratory's internal and external activities. One important aspect of the D-4 analyses is the analysts' ability to conduct a fully objective and independent analysis and to reach whatever conclusions the data and analyses dictate—the studies are objective and unbiased.

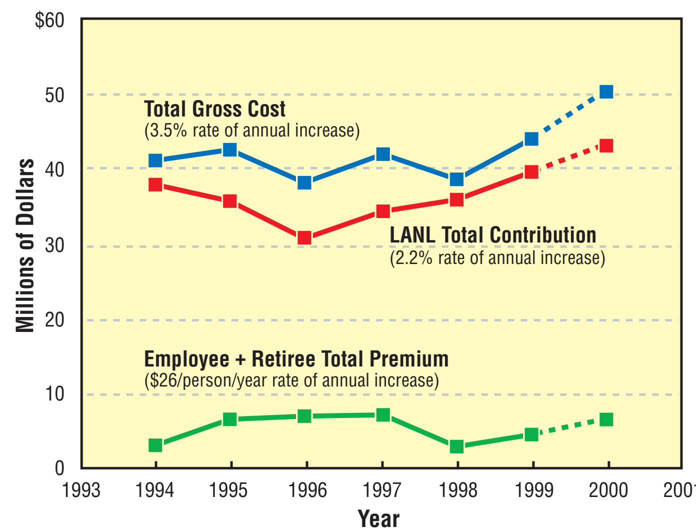
Studies conducted recently on behalf of Laboratory management include:

- Los Alamos Health Care Study
- Regional Airport Study
- Diamond Drive Traffic Study
- Los Alamos Science Complex Construction Alternatives Study
- Gross Receipts Tax Study
- Various regional economic impact analyses
- Economic impact analysis of moving 1,000 LANL employees to downtown Los Alamos
- LANL electric demand forecasting
- PC Platform Alternatives Study

One example of the importance of these capabilities to the Laboratory is the gross receipts tax study commissioned by the Director's Office in support of the Laboratory lobbyists' efforts at the New Mexico State Legislature. Lobbyists used the study results in briefings and politicians used them in statements in the Tax and Finance Committee hearings. The results indicated the potential negative impact on northern New Mexico if the University of California had to pay gross receipts tax on the project funds it receives from the federal government. Proposed changes in the law would have cost the Laboratory an estimated additional $60 million that might have come out of project funds.

A main contention of Laboratory employees has been that the Labora-





Decision support and analyses are crucial to examining the implications of the Laboratory's internal and external activities.

tory's health insurance costs are higher than those of other employers. The Los Alamos Health Care Study showed that the Laboratory's health insurance coverage is superior to the health insurance coverage offered by most U.S. employers while at the same time costing employees significantly less. This study was briefed before the Lab's Senior Executive Team and at an All-Manager's Meeting.

Sometimes study conclusions conflict with the management's desired outcomes. In such circumstances, the analyst must be able to support the conclusions with clear analyses and hard data. For example, the Regional Airport Study concluded that a regional airport in the vicinity of Española would not attract viable commercial airline carriers and would not provide the Tri-County region with more proximate airline service. Management personnel were on record publicly supporting the establishment of a regional airport in this location. However, after receiving a briefing on the study and participating in the extended discussions that followed, the issue was tabled.

Generally, these studies are conducted entirely by D-4 staff members; however, the analyses often rely on information and data gleaned from other organizations within the Laboratory and the University. The health insurance study relied upon the Laboratory's Benefits Office as well as personnel from the UC President's Office for information and data on the plan. Group members also met with Blue Cross/Blue Shield personnel as well as the University's outside auditors to obtain data and information pertinent to the study. The auditors were briefed on the study results.

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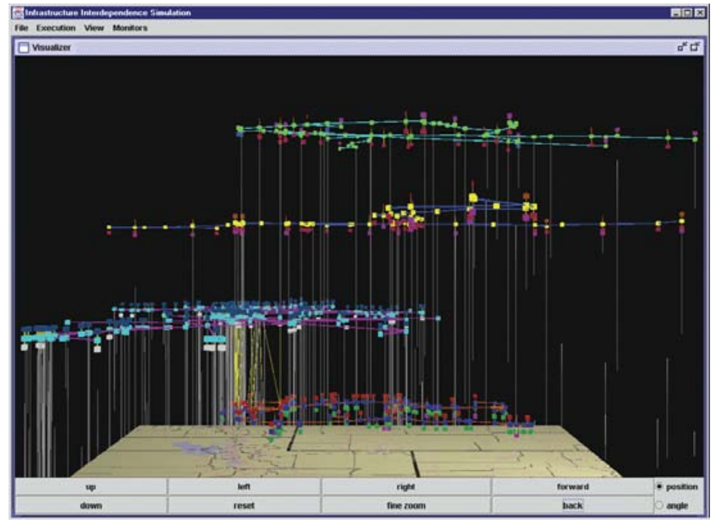
Interdependencies Among Energy Infrastructures

Over the past five years, the Laboratory's analysis of the U.S. electric power grid has expanded into the broader areas of energy generation and transmission infrastructures. We now analyze natural gas pipelines, petroleum liquid networks, telecommunications networks, and the coal infrastructure. The security of the nation is critically dependent upon these infrastructures to provide an appropriate quality of service.

Energy infrastructures typically employ feedback loops among various networks that are critical to delivering the network's products. For example, a gas-fired electric generating plant requires a steady supply of natural gas. The natural gas pipelines may utilize electric-powered compressors to maintain sufficient pressure, setting up an interdependency. Understanding interdependencies is therefore critical to understanding these complex coupled systems. We feel that an inflexible modeling and technology base has hampered prior analysis. Existing modeling and simulation technologies have successfully analyzed single infrastructures but these technologies have severe limitations when it comes to modeling interdependent infrastructures.

The Interdependent Energy Infrastructure Simulation System (IEISS) is currently being applied to a number of energy infrastructure issues across the country dealing with human-created or natural disasters (see examples below in the figures). The capability is used to address a wide variety of infrastructure questions within states/regions and across the country. It also allows us to identify and understand, in depth, the infrastructure interdependencies during normal operations as well as during disruptions. IEISS provides analysts with the ability to assess the technical, economic, and national security implications of these systems' configurations from an interdependencies perspective. Using the IEISS tools, we can create a detailed analysis and understanding of entire interdependent infrastructures, including their components and couplings, in a manner far beyond what we could previously. We envision a diversity of possible applications for analyses based on IEISS. Our analysis efforts are intended to assist decision makers in the areas of policy analysis, investment and mitigation planning, education and training, vulnerability and criticality assessments, consequence management, and real-time crisis assistance.

Additionally, IEISS can be used as a research tool for investigating fundamental issues related to real-life, nonlinear, coupled, complex networks. Our analyses focus primarily on normal or off-normal conditions arising within



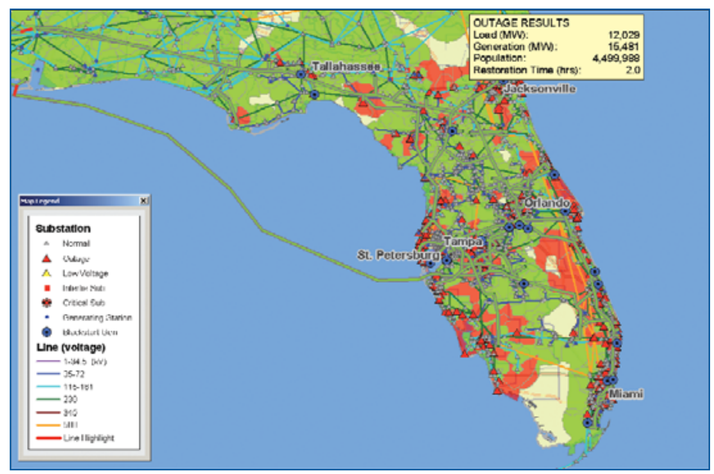


Fig. 1 Network interdependencies identified for the Salt Lake City, Utah, area.
Fig. 2 Natural gas-electric power interdependency impacts in the Florida peninsula.

each regional network or within a local network serving one or more sites of interest. Site-specific analysis can also include service and outage area estimates, as well as estimates of outage duration based upon component criticality considerations. Additional attention is often given to an appropriate interpretation of system-level metrics that result in degradations to commercial delivery capability and to varying system conditions throughout a typical year.

Interdependency analysis often includes three components: Regional System Analysis, Local Operational Area Analysis, and On-Site Analysis. These analyses use both quantitative and qualitative processes; with a better opportunity to use quantitative processes the closer the network is analyzed to the site of interest. In electric networks, for example, identification of transmission/subtransmission lines critical for power transfer with adjacent control areas, within the control area, subtransmission system configuration, and generating units available to support local system demand and voltage stability are considered.

Modeling network performance is a fundamental part of the analysis process and is used as a verification tool, to estimate of system performance under adverse operating conditions, for representing infrastructure in a geographic information system format, and for graphic presentations in written reports.

IEISS was used in studies that served as preparation for the 2002 Salt Lake City Olympics. Figure 1 shows an abstract three-dimensional visualization of major energy infrastructure networks (crude oil pipelines, petroleum product pipelines, electric power transmission lines, and natural gas pipelines) overlaid on a map of Utah identifying key Olympic venue sites; the various vertical lines identify interdependencies between the systems. IEISS has also been used to investigate loss of critical natural gas pipelines in Florida, to assess electric component outage sequences during the August 2003 regional electric outage, and to estimate the widespread outage areas caused by Hurricane Isabel in September 2003. Figures 2, 3, and 4 highlight these applications.

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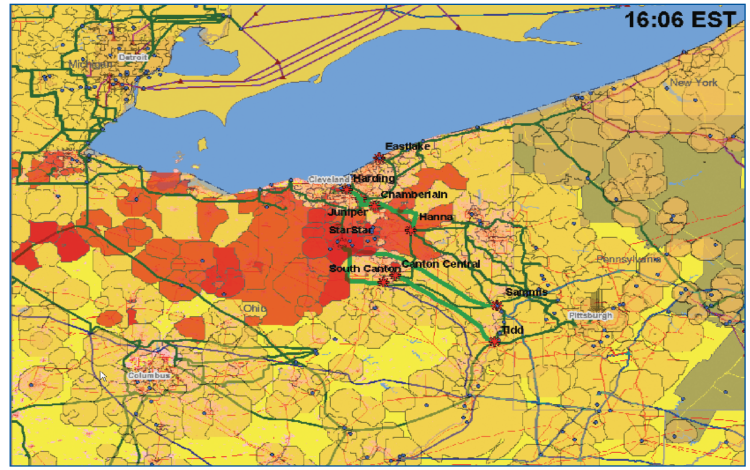


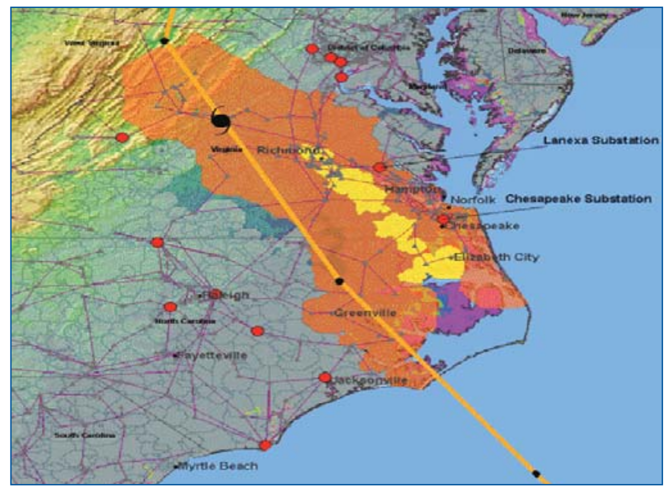


Fig. 3 Regional voltage stress simulation for the August 2003 electric outage.
Fig. 4 Estimated wind damage contours for Hurricane Isabel.

Quick Urban and Industrial Complex (QUIC) Dispersion Modeling System

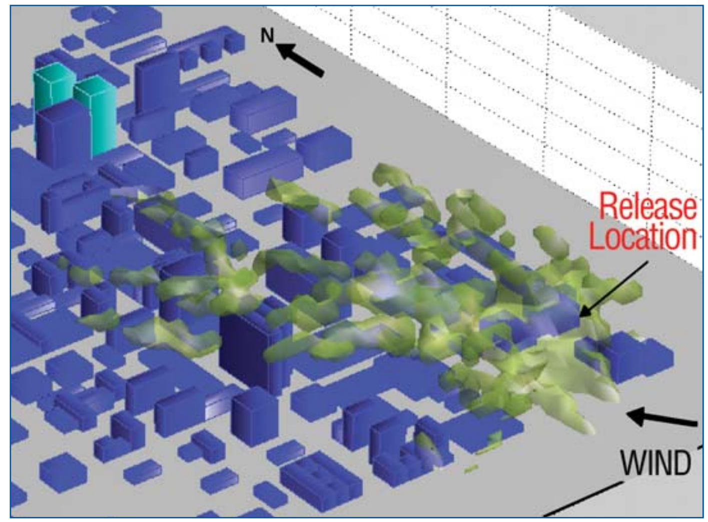
To respond to the threat of a terrorist releasing a chemical or biological (CB) agent in a city, Laboratory and University of Utah researchers have developed a fast-response urban transport and dispersion modeling system. Fast models are essential for vulnerability studies where many cases must be simulated in a limited amount of time or for emergency response scenarios when an answer is needed quickly. However, the presence of building makes the dispersion of a CB agent released in an urban area difficult to predict. Most emergency response dispersion models currently in use have little or no building "awareness." The Quick Urban and Industrial Complex (QUIC) fast-response urban dispersion modeling system computes the three-dimensional wind patterns and dispersion of airborne contaminants around clusters of buildings. The system is comprises a wind model, QUIC-URB; a Lagrangian dispersion model, QUIC-PLUME; and a graphical user interface, QUIC-GUI.

Vulnerability Studies, Training, and Emergency Response

QUIC provides credible models of agent dispersal patterns in an urban environment, while still achieving very quick turnaround and ease-of-use. It is ideal for planning and assessing many CB agent attack scenarios. It could be used in next-generation training with unscripted tabletop exercises and immediate feedback. Because of its speed, it could be run around the clock at a military base or high-profile target (e.g., D.C. Mall), ingesting local wind measurements in realtime.

We developed the QUIC tool with an easy-to-use graphical user interface that can compute 3-D wind and concentration fields around building complexes in less than a minute. A novel approach for the estimating of turbulent mixing in building wakes was required for good comparisons between model simulations and measurements. The graphical interface permits easy visualization of concentration patterns, agent travel, wind fields, and deposition patterns.

QUIC can also simulate deposition of agents on walls and rooftops and on the ground. Consequently, it can provide guidance for investigators taking "swipes" of surfaces in post-event investigations. Normally, fast-running models can only describe averaged deposition and offer no guidance for the relative importance of streets, walls, roofs, or alternate sides of street canyons that may be collecting deposited agents. QUIC's deposition details can help the investigations into events and the cleanup in the aftermath of CB events.



QUIC-PLUME simulation of CB agent transport and dispersion in downtown Salt Lake City, Utah. The agent cloud is quickly lofted into the air because of the presence of tall buildings.

Sensor Siting

The QUIC code is also the underlying engine in the QUIC Sensor Siting tool, used for determining the optimal placement of CB agent sensors around building complexes. Early detection of a bioweapon attack—which might go unnoticed and unpublicized—would allow timely medical intervention that could save hundreds or thousands of lives. Alarms from judiciously placed chemical agent sensors could trigger mitigation strategies such as closing ventilation intakes. Because of high cost and operational logistics, most facilities will only be able to site a handful of CB sensors. The QUIC Sensor Siting tool gives quantitative answers on where to place sensors around a building complex to maximize the probability of detecting a CB agent attack.

We developed the Sensor Siting tool to produce maps showing the best (and worst) places to put CB agent sensors around building complexes. The maps show the probability of detection of releases of a user-selected, source strength for the conditions of interest.

QUIC fills a significant void between fast, but low-fidelity, conventional plume dispersion models and high-fidelity, but slow, computational fluid dynamics models. The QUIC tool satisfies a critical need in the CB counter-measures arena.

The Laboratory's QUIC team collaborated with the University of Utah, Oklahoma University, Arizona State University, and University of California at Riverside on this project.

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Applied Transportation Studies

Unlike traditional static models that can only model transportation and flows at gross levels, the Transportation Analysis Simulation System (TRANSIMS) employs dynamic "bottoms-up," disaggregated modeling techniques. The advantage of the individual carrier/shipment simulation approach is in the level of detail with which the nation's transportation system can be represented—from trucks and goods moving among counties and within regions to national multimodal traffic flows including cross-border trade with Mexico and Canada. This strength can then be exploited for transportation policy and for security and infrastructure investment purposes.

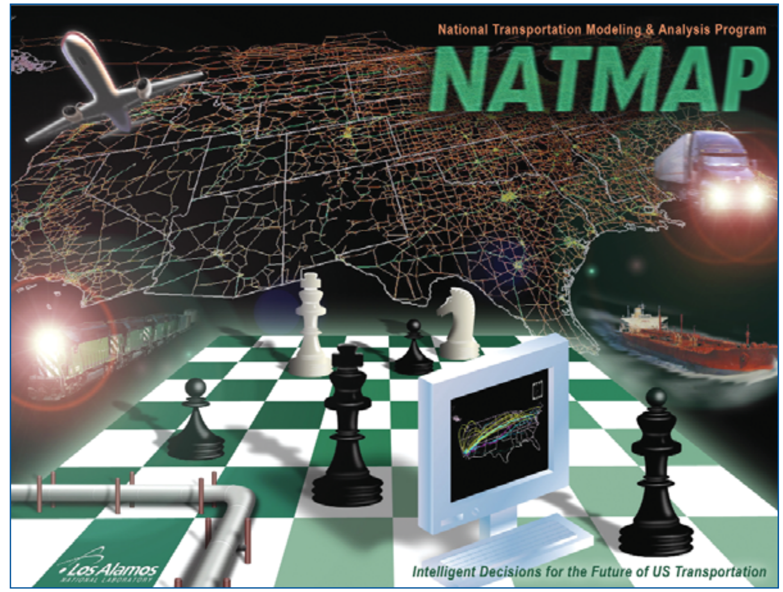
TRANSIMS has been used to model several different situations including:

Traffic Around Los Alamos. The TRANSIMS team evaluated the proposed conversion of Diamond Drive on Laboratory property from four to three lanes. This conversion was intended to address safety issues caused by left turns from Diamond Drive onto two crossing streets and the lane widths being nonstandard. Widening the road was not an option because of the expected high cost. The results were used in planning by Los Alamos County Transportation Division. Further work evaluating traffic security options is being performed.

Coal Over Rail. The Coal over Rail creates a simulation and network to model the movement of critical energy commodities countrywide in support of crisis response planning. Initial efforts will focus on simulating coal shipments from mines in the western U.S. to various power plants in the West and Midwest. Energy disruptions resulting from the loss of various connectors will be observed from the simulation and carried forward to interdependency analyses.

NATMAP-NM (National Transportation Modeling and Analysis Program-New Mexico). The New Mexico Department of Transportation (NM-DOT) is proposing a partnership with the Laboratory to develop and deploy the first statewide, multimodal transportation model in our nation's history. This initiative will adapt these simulation technologies into a tool set for use within metropolitan areas, statewide, state-to-state, and nationally.

The D-4 TRANSIMS team collaborated with the Laboratory's CCS-5 group and FWO Division, the U.S. Department of Transportation, New Mexico Department of Transportation, University of New Mexico, New Mexico State University, New Mexico Tech, and the Metropolitan Planning Organization of Albuquerque.



The National Transportation Modeling and Analysis Program simulates transportation infrastructures at any level of detail—from trucks and goods moving among counties and within regions, to national multimodal traffic flows including cross-border trade with Mexico and Canada.

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Visualization

Whether collected from sensors, data is generated synthetically from computer simulations, or from mathematical models, the challenge of exploring and analyzing huge and often complex, high-dimensional data sets is often best met through computer-mediated visualization, or more generally "perceptualization." By adding other sensoria such as sound and touch and lowering the thresholds to interactivity, the human cognitive system can be more closely coupled with the problem domain being studied.

The division has addressed a broad range of problems using visualization techniques. The problems include transportation and population mobility, epidemiology, energy networks and interdependencies, threats and effects of terrorist attacks, military modeling and simulation, ultrascale supercomputing, Internet traffic analysis, and intrusion detection.

Scientific, geographic, statistical, and information visualization tools often play an important role in these tasks. Modern graphics and visualization tools are grounded in the much older arts such as cartography, painting and illustration, graphing and charting, drafting, photography, cinema, and even cartooning. Advances in hardware and software for the entertainment and consumer products industries have made extremely high-quality, high-speed computer graphics available at very low cost.

The following are some of the projects that team members have contributed to:

The Nuclear Earth Penetrator Project System (NEPPS) included a 3-D interactive visualization of hardened underground targets using Java 3D.

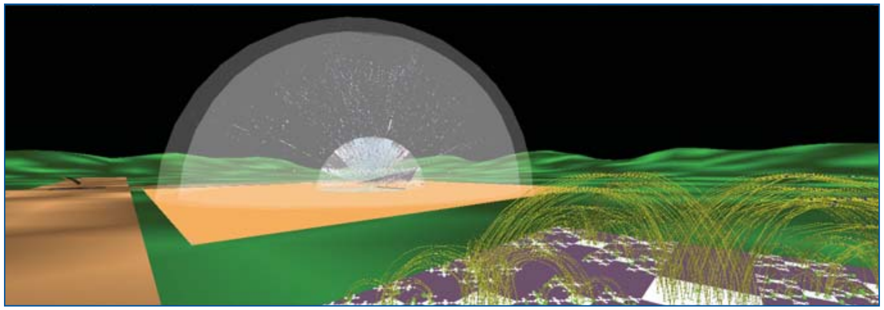
The ShadowJack project applied generative analysis to Future Combat System (FCS) in the Joint Virtual Battle Laboratory (JVB) for DoD, resulting in an automated exploration of the simulation space of the FCS with visualization of the simulation.

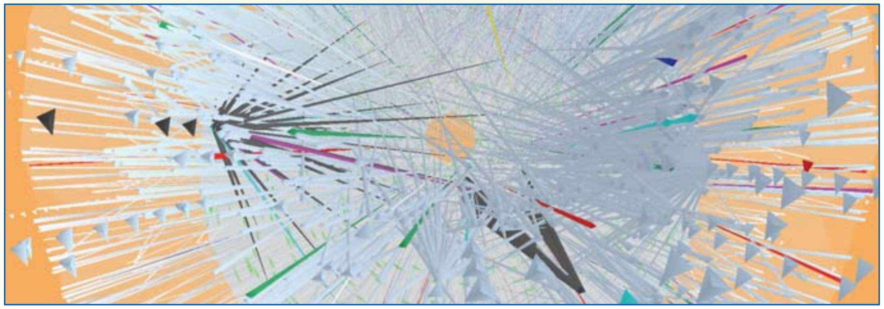
Visualization tools were developed to analyze of the structure and dynamics of ultrascale supercomputing architectures. This analysis created an interactive, immersive visualization of the processing nodes, switching fabric, and message traffic in the 12,000 node ASCI 'Q' Supercomputer for the ASCI Ala Carte project.

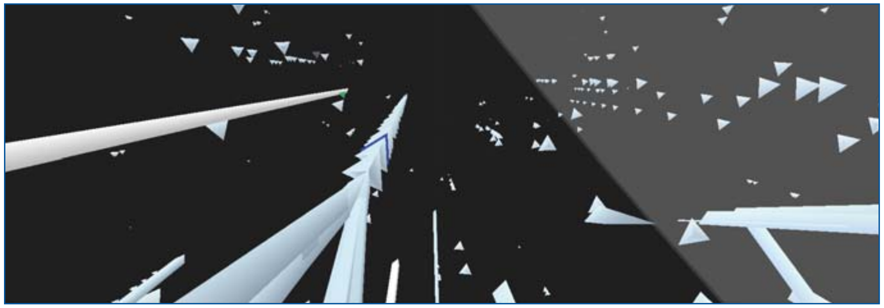
Collision detection was added to the Flex Sim commercial simulation package.

The Network Intrusion Detection visualization developed an interactive, immersive visualization of network traffic at the Laboratory's firewall to support exploration, discovery, and analysis of threats to the Laboratory's yellow and green networks.

Numerous division projects depend directly on the development of scripts,







The images above and on the following page are examples of D Division's visualization capabilities. The division's visualization tools have been applied to problems ranging from data flow architecture and traffic simulations to energy interdependencies and potential terrorist activity.

applications, and visualizations using the commercial Geographical Information System suite from ESRI including ArcView and ArcInfo.

Underlying the above projects are a number of ongoing research and development efforts in the following areas: metaphor mapping and reification; composable data flow architectures; information and situational awareness environments; general purpose computation with special purpose graphics processing engines; tele-immersive environments for collaboration; and visualization clusters.

The D Division Visualization Laborora-tory provides an environment suitable for small group presentations and working sessions in a media-rich environment. A large stereo-capable powerwall with surround sound is the centerpiece. We also have a FakeSpace Laboratories Boom and numerous highperformance graphics systems with flat panel displays and projection systems.

The Visualization Team collaborated with the DoD Joint Virtual Battle Laboratory, Sandia National Laboratory, the ASCI project, UNM's High-Performance Computing Center, George Mason University, FakeSpace Laboratories, Stanford University, University of York, Zyvex Laboratories and internal Laboratory organizations Nonproliferation and International Security (NIS), Center for Integrated Nonotechnologies (CINT), Los Alamos Neutron Science Center (LANSCE), and Laboratory groups CCN-5, CCN-8, and CCS-3 on these projects.

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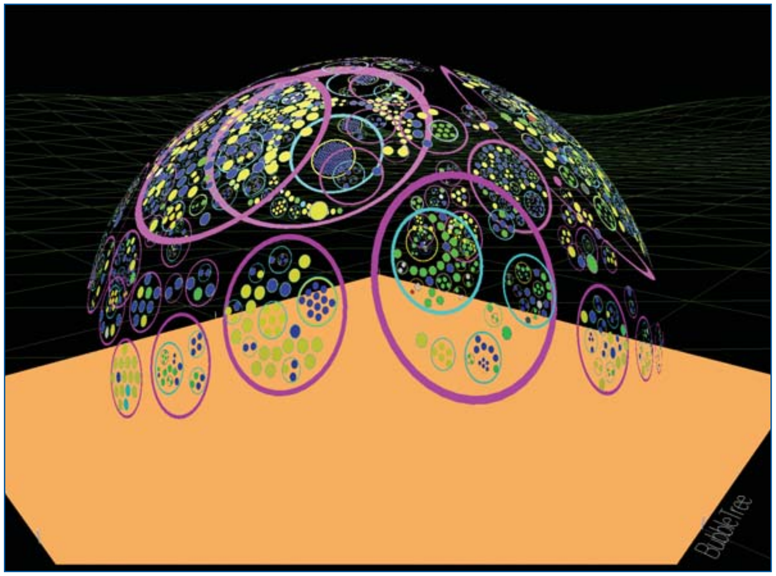
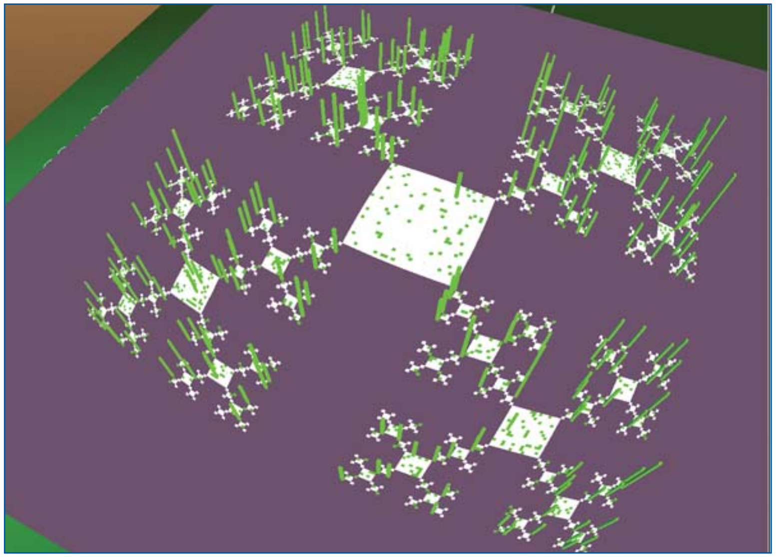




Decision Support for Critical Infrastructure Protection

Decisions affecting our nation's critical infrastructures are too important to be made without performing an analysis beforehand that carefully weighs the benefits of reducing risks against the cost of protective actions. The most effective way to examine these tradeoffs is to utilize a decision support system that incorporates the results of threat assessments, vulnerability assessments, and analyses that are based on comprehensive, advanced modeling and simulation. Governments (federal, state, local) and industry decision makers can use this type of decision support system to prioritize protection, mitigation, response, and recovery strategies as well as to support emergency response exercises and provide real-time support during crises and emergencies.

The Critical Infrastructure Protection Decision Support System (CIP/DSS) is a joint project undertaken for the U.S. Department of Homeland Security in August 2003 by Argonne National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory. It provides decision makers with analytical tools for setting priorities to reduce infrastructure vulnerabilities. It will include all major critical infrastructures (electric power, water, telecommunications, food, agriculture, etc.) and key assets (dams, bridges, shopping centers, etc.) and their primary interdependencies. Activities in subsequent years will improve the integration, resolution, and fidelity of the individual infrastructure models and greatly improve the interdependencies models. It will also incorporate vulnerability and threat data in order to ultimately provide a "risk-based" prioritization decision support system

Examples of issues that this decision support system will be designed to address include the following questions:

What are the consequences of attacks on our nation's infrastructure in terms of national security, economic impact, public health, and conduct of government, including the consequences to infrastructures?

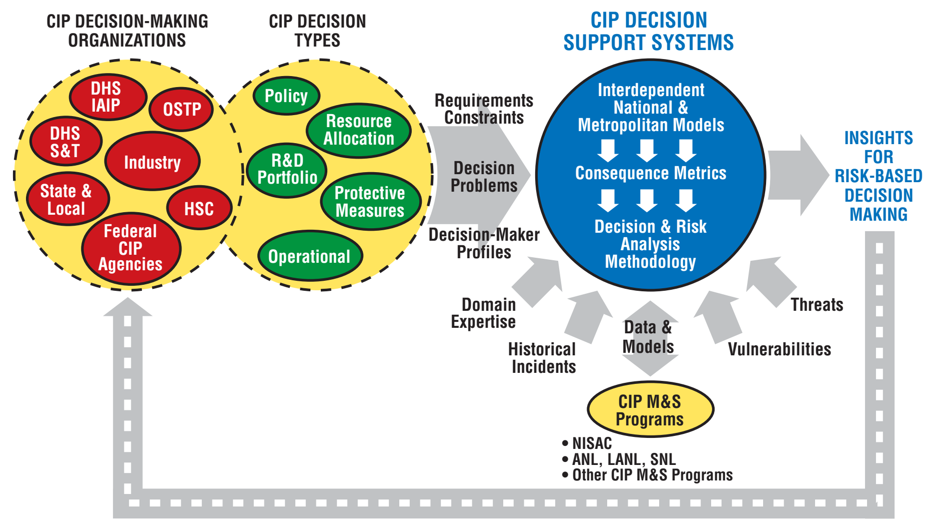
Are there choke points in our nation's various infrastructures? Where are the areas where one or two attacks could have the largest impact? What are the choke points?

After incorporating consequence, vulnerability, and threat information into an overall risk assessment, what are the highest risk areas?

What investment strategies can the U.S. make that will have the most impact in reducing overall risk?

So far the project has developed systems dynamics models for twelve interdependent urban critical infrastructures, accounting for nearly 1,700 variables, and is running these models for a pair of case studies—a widespread telecommunications outage that perturbs numerous other infrastructures, and a livestock pathogen that affects the agriculture, food, and public health sectors. Initial results demonstrate that this model provides insights into the feedback loops between critical infrastructures.

We are collaborating with Lucent Corp.; Booz, Allen, Hamilton; Washington State University; Georgia Tech; and the University of Southern California on this project.



This type of decision support system can be used to support crisis planning.

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Radiation Transport

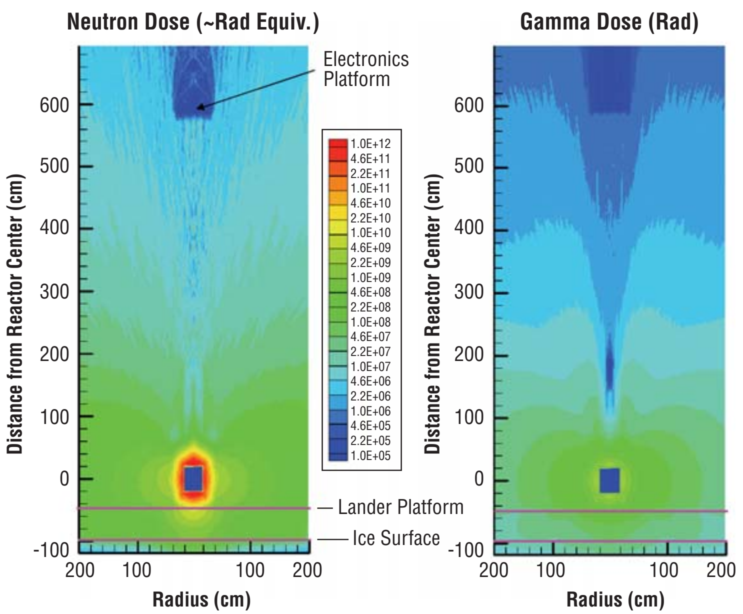
Researchers need to analyze nuclear systems with a state of the art radiation transport code to solve issues in nuclear design, safety, and security.

Monte Carlo N-Particle Extended, referred to as MCNPX™ (MCNP extended to all particles and all energies), is an advanced three-dimensional Monte Carlo radiation transport code. It is capable of tracking 34 particle types (including four light ions) over a wide range of energies. The code uses standard evaluated data libraries for proton, neutron, and photonuclear interactions, many extended to 150 MeV, along with physics models when libraries are not available. MCNPX is supported on all UNIX, Linux, and PC platforms, and can be multi-processed with Parallel Virtual Machine (PVM) or Message Passing Interface (MPI).

MCNPX is ideal for a wide variety of problems, particularly in accelerator and space science, and has recently emphasized the importance of looking at charged particles in traditional low-energy problems. The user can now fully track all particles rather than assume their energies are deposited locally upon production. The code offers a choice of either evaluated nuclear data or models, which greatly increases the user's flexibility to investigate problems formerly limited by available data libraries. The code also includes analysis tools commonly used in high-energy physics simulations, but little known at lower energies. We are constantly expanding the capabilities of MCNPX to new physics models, new particles such as heavy ions, and unusual energy regions, as well as adding new tallying and variance reduction methods. The addition of a transmutation capability will expand the range of the code in time to track the evolution of the residual nuclei, letting us address critical issues involving the transmutation of waste. Currently our sponsors can use alpha versions, and we are developing transmutation capability in FY04.

Major code applications include the following:

- Shielding design and evaluation for high- and low-energy applications including accelerators, reactors, spacecraft, and cosmic rays;
- Geochemical analysis, for example, the Mars Orbiter data that resulted in the recent verification of water on Mars;
- Dosimetry and health physics calculations;
- Design of reactor and accelerator waste transmuters;
- Standard MCNP criticality capability and reactor design;
- Materials damage analysis (single event effects, bulk damage, etc.);



MCNPX calculation of the dose surrounding the HOMER-15 Mars Polar Lander (15 kWt over 5 years).

- Medical applications including proton, neutron, gamma, and electron therapy;
- Neutron scattering for materials research;
- Neutral and charged particle radiography; and
- Detector design and analysis for threat reduction.

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Space Reactors

Space fission power and propulsion systems could enable numerous exciting space missions. Space fission systems are especially attractive for space missions requiring high power and/or space missions operating in environments where solar power is not readily accessible. Potential missions include ambitious, long-duration missions to the lunar or Martian surface, and NASA's Jupiter Icy Moons Orbiter (JIMO).

Los Alamos began a low-level effort in the mid-1990s to rejuvenate interest in space fission power and propulsion systems. The focus of the Laboratory's approach was on simple, highly testable systems that could enable missions of interest. In 1998, Los Alamos began working closely with NASA to design and fabricate potential space fission power reactor cores (unfueled), with a particular emphasis on testability. In 2000, realistic testing of one such core was initiated, using resistance heaters to closely mimic fission heat deposition. In 2001, the core was coupled to a power conversion subsystem and an ion thruster to provide an end-to-end nuclear electric propulsion breadboard. In 2001, NASA began to express high-level interest in the development of space fission systems. The D-5-led team continues to perform design, analysis, and testing related to a variety of space reactor concepts and to demonstrate that innovative, highly testable space fission systems can be devised for numerous missions. Los Alamos is currently the reactor design lead for NASA's JIMO Project.

The proposed designs facilitate conversion of paper reactor designs into actual working hardware. Designs emphasize test effectiveness, i.e., the ability to complete highly realistic non-nuclear testing. Systems are designed to be resistant to radiation damage and to have modest fuel burnup requirements, further increasing the worth of realistic non-nuclear testing. Numerous hardware tests have been performed to confirm the potential performance of the proposed systems. A JIMO-class reactor is shown here.

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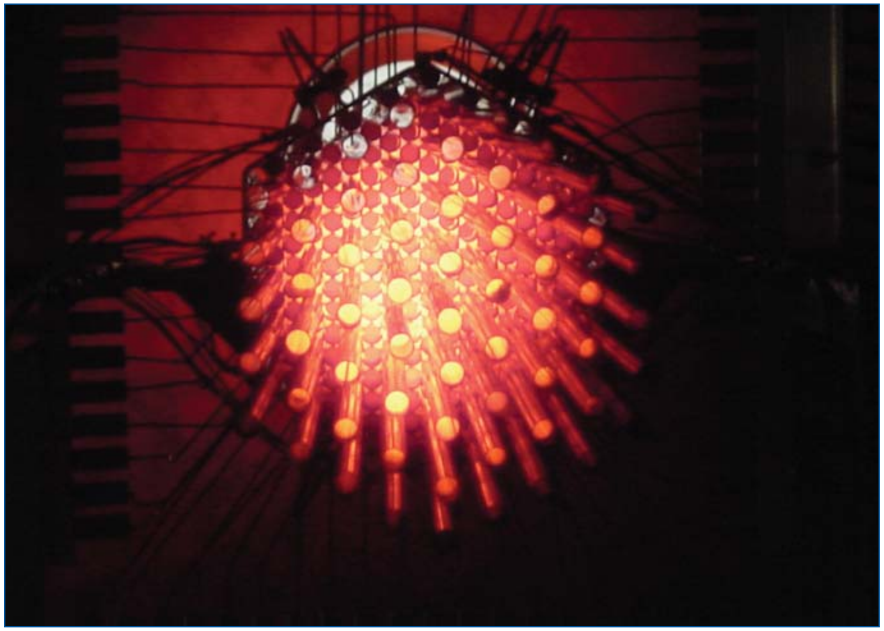

SAFE-100 Core Simulator Test

Thermal-Hydraulic System Code Development and Applications

Continuing to ensure the safety of nuclear power plants and other nuclear reactor facilities, D-5 develops and applies best-estimate thermal-hydraulics system analysis codes.

Independent safety analyses are performed using best-estimate thermal-hydraulic codes to assess reactor safety. The TRAC/RELAP Advanced Computational Engine (TRACE) code being developed by Los Alamos and other institutions for the NRC has been used to model nuclear power plants and simulate postulated accident scenarios to show that the power plant safety systems can bring the plant to safe shutdown conditions.

The TRACE (formerly Transient Reactor Analysis Code) thermal-hydraulic system code has been under continuous development by Los Alamos for the NRC since 1970. The TRACE code continues to evolve with increasing understanding of complex two-phase, multicomponent fluid phenomenology. After sponsoring multiple codes for over two decades, the NRC has selected TRACE as the sole platform for future development. The Laboratory plays a key role in an ambitious multi-institutional development program designed to modernize and expand the existing code capabilities.

As the NRC considers pre-application review of new reactor concepts such as the Pebble Bed Modular Reactor (PBMR) and the Simplified Boiling Water Reactor, the Laboratory has been in a position to provide the needed developmental and analysis support.

In support of the Accelerator Transmutation of Waste program, TRACE has been updated to include liquid-metal fluid properties and to enable the tracking of trace species. A TRACE model of the Los Alamos Development of Lead-alloy Target Applications (DELTA) loop facility, a liquid lead-bismuth materials test loop, has been developed and used to simulate actual test runs.

Recent TRACE code development tasks have sought to provide new Pebble-Bed core materials and component models as well as to revise channel modeling for the simplified boiling water reactor. Enhancements have included three-dimensional fuel sphere-coolant heat transfer capabilities for the PMBR and modeling capabilities for the water rods and partial-length fuel rods associated with the Enhanced Simplified Boiling Water Reactor (ESBWR) fuel designs. Additional implicit heat structure development support for KAPL will reduce run times on key design basis accident analyses. In the future, we look toward developmental tasks in support of the GEN-IV reactor concepts as well as the potential for hybrid code development, coupling TRACE to computational fluid dynamic (CFD) and/or reactor physics analysis kernels.

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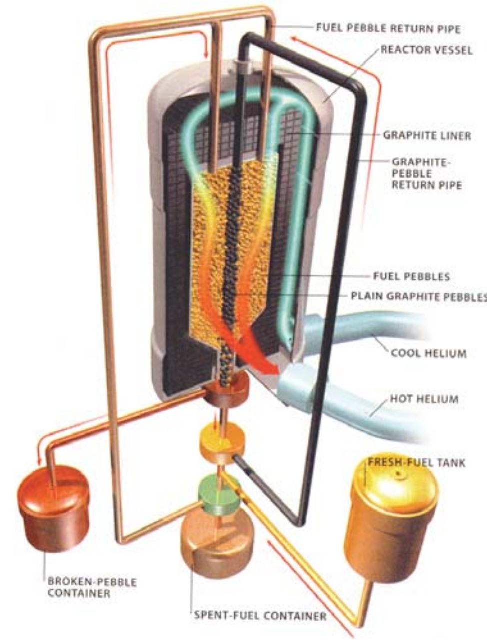


Side view of a Pebble Bed Modular Reactor (Courtesy of Technology Review, Illustration: Slim Films, Source: Exelor)

Nuclear Weapons Surety Modeling

Nuclear weapons safety issues are an ever-present concern at the Laboratory. D-5 has developed an effective approach to systematically identify and evaluate risks for any of these issues.

We use formal logic models, called scenario possibility trees, to identify accident scenarios. They are designed for problems involving complex, poorly understood phenomena, and provide a knowledge base structure as well as a framework for expert opinion. Simplified physical models are used to screen identified scenarios. These scoping tools are coordinated with possibility tree solutions (accident paths). Scoping tools model the most important physical processes associated with nuclear weapons safety and must be flexible in response to each proposed physical phenomenon. A good scooping tool guides and focuses development of more detailed models and experiments of weapons phenomena that drive risk.

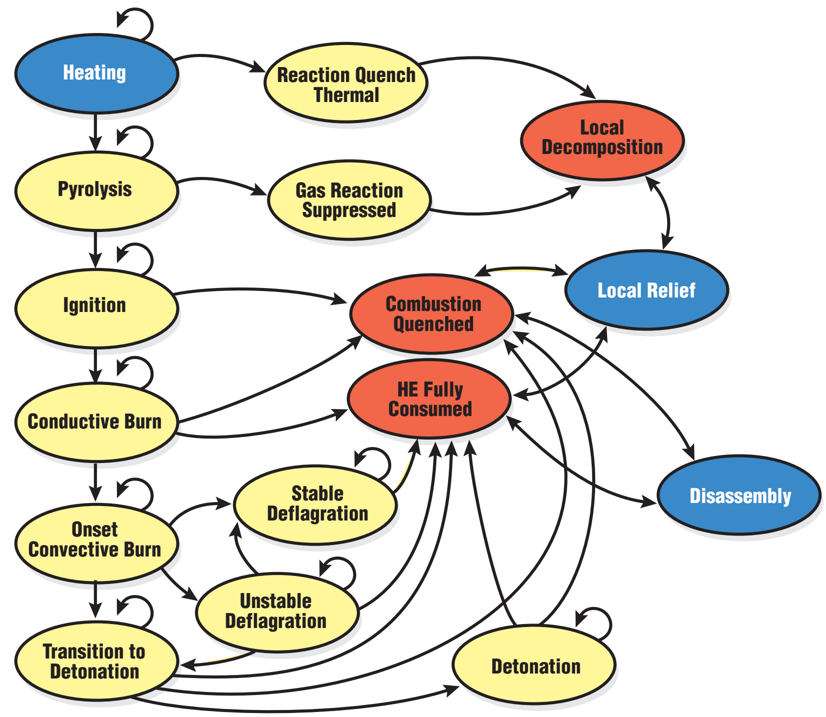
Fault trees are a type of formal logic models that have been used for years in the aircraft, nuclear reactor, and other industries. Our possibility trees are related in that they also use deductive logic and the gates have mathematical equivalents, but they represent the details of physical processes such as heat transfer, rather than events such as pump failure. The solutions of possibility trees for safety issues are individual accident paths.

Possibility trees have evolved at the Laboratory out of the need to deal with complex, poorly understood weapons phenomena. They can represent the entire weapons safety knowledge base: experiment results, expert opinion, and model calculations within the same framework. When speculative information is all that is available, alternative views are easily represented.

The solution of possibility trees for complex phenomena often yields a large number of accident paths. Researchers need a means to screen this large number of paths. Screening the results is not as much a nuisance as might be supposed. We have often discovered heretofore unknown, but important, paths by examining a solution set. Some of these have been termed the "unknown unknowns" in other approaches.

We screened using scoping tools that are focused on a particular subset of the possibility tree solution paths. We create these by using the knowledge base to identify the most important physical processes, enough to give approximate solutions to boundary conditions. We improve and confirm our models with other, more detailed models and experiments when these are available.

Practically any accident scenario with interesting consequences is a valid application of our surety modeling approach. In the diagram, we focus on cook-off of high explosives.



This surety model shows the possible outcomes of slowly heating a conventional high explosive (HE).

We have developed two possibility trees for cook-off. One shows the possible outcomes of slowly heating a conventional high explosive. Another shows possible sequences of physical processes that could lead to a violent outcome.

As the above diagram shows, a widely varying set of outcome states is possible, ranging from a thermal quench that produces only mild damage to the explosive up through a detonation that efficiently releases the chemical energy contained in the explosive. In general, loops like those seen on some of the graph nodes above refer to cyclic subprocesses that occur within the context of the node. The loops shown here refer to reaction spreading processes. These serve to inhibit reaction locally and delay thermal explosion at a given location. Meanwhile, a larger volume of the surrounding explosive has enough time to become primed for explosion. In the absence of reaction spreading, a relatively small volume of explosive might be involved in an energy-releasing reaction. Reaction spreading leads to a larger fraction of explosive becoming involved and can therefore lead to more violent outcomes. This phenomenon plays an important role in determining the level of cook-off violence and was discovered with the aid of the process trees we developed.

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Assessing Vulnerability and Consequences

Los Alamos has been working with the DOE, NRC, and Sandia National Laboratories to develop a robust methodology to analyze the threats to nuclear installations in the wake of the attacks on 9/11. This work has led D-5 to a set of capabilities and tools that allow for a flexible approach to analyzing vulnerabilities based upon the threat to a facility. Los Alamos is capable of providing the following information in support of vulnerability assessments:

- Identify threats
- Identify targets
- Identify possible attack scenarios
- Examine likelihood of scenarios
- Determine consequences
- Evaluate protection
- Analyze for improvements

The technology and experience used to assess postulated nuclear facility accidents and their consequences can also be used to assess postulated nuclear attack scenarios. These technologies include probablistic risk assessment, interior aerosol transport modeling, and atmospheric dispersion modeling.

Probabilistic Risk Assessment (PRA). Los Alamos uses risk as a metric for comparing different attack scenarios. Risk requires some estimate of the probability that different scenarios are attempted and the conditional probability of a range of consequences given the attempt. The Laboratory's primarily uses the Logic Evolved Decision (LED) tool to evaluate risk. The LED approach uses logic models and approximate reasoning (AR) to produce rigorous estimates of attempt probability using qualitative and subjective inputs. Instead of asking an expert to make a direct estimate of attempt probability for each member of a set of scenarios, the expert's evaluation process is used to determine which attack scenarios are most attractive to different classes of terrorists. Then the values of the factors used in estimating the attractiveness for each scenario are collected, and the evaluation process is used on each scenario to consistently and systematically produce an attractiveness ranking of the scenarios.

Interior Aerosol Transport Modeling. Los Alamos uses many tools and methods to estimate the transport of aerosol particles through buildings and ductwork to the environment for postulated accident scenarios. These tools range from simple hand calculations to complex three-dimensional flow codes. Calculating aerosol transport in buildings is fundamental to most nuclear safety issues.

Atmospheric Dispersion Modeling. Atmospheric dispersion is the key transport mechanism for the release of most hazardous materials, most importantly nuclear materials. To evaluate this transport mechanism, D-5 utilizes industry standard and in-house tools to evaluate the atmospheric dispersion.

We can model the spectrum of distances typically of concern in far-field atmospheric dispersion where simple Gaussian models are employed to near-field atmospheric dispersions that require complex three-dimensional flow fields be solved in order to accurately capture the concentration of aerosols.

Some of the primary tools for atmospheric dispersion modeling include the Laboratory-modified INPUFF code, the QWIC-URB code, and the Laboratory's HIGRAD code. The INPUFF code takes a far-field approach, utilizing a simple Gaussian puff model for computational efficiency. At the other extreme, the HIGRAD model uses a large-eddy CFD approach to resolve three-dimensional flow field effects with close to real meteorology (near-field atmospheric dispersion). As an intermediate approach, the QWIC-URB model expands on the Gaussian approach by employing empirically based, multidimensional effects in the building wake regions. This intermediate approach yields improved accuracy over the far-field approach without the computational penalty associated with a full CFD analysis.

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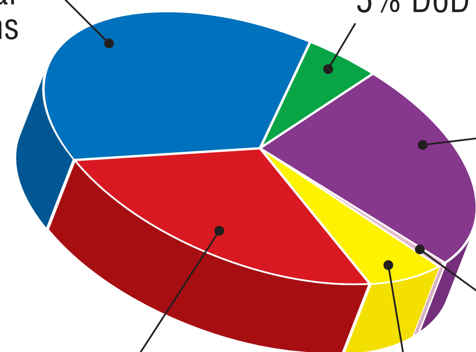
Decision Applications Division

Appendix

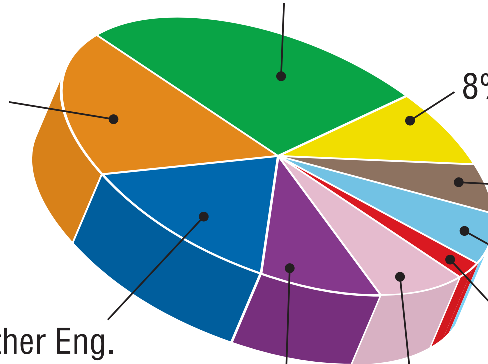
Decision Applications Division Statistics

Fiscal Year 2004 (FY04) projected budget by focus area—$69.7 million in total.



Nuclear Weapons	37%	$25.8 M
DoD	5	3.5
Other	25	17.4
LDRD	1	0.7
Energy & Environment	7	4.9
Homeland Security	25	17.4

Technical staff members (TSMs) in the division by discipline—183 TSMs in total.



Nuclear Engineering	26%	48
Mechanical Engineering	8	15
Mathematics	6	11
Computer Science	7	13
Chemistry	3	5
Statistics	8	15
Physics	9	16
Engineering Other	14	26
Other Disciplines	19	34

Acronyms and Abbreviations

A

ACTD Advanced Concepts Technology Development
AFLP amplified fragment length polymorphisms
AL Albuquerque
api application program interface
AR approximate reasoning
ARPA Advanced Research Projects Agency
ASCI Accelerated Strategic Computing Initiative
AWSIM air warfare simulation

B

BASIS Biological Aerosol Sentry and Information System
BDA battle damage assessment

C

C Chemistry Division
C2 command and control
CB chemical or biological
CDC Centers for Disease Control
CFD computational fluid dynamic
CINT Center for Integrated Nanotechnology
CIP/DSS Critical Infrastructure Protection Decision Support System
CMR Chemistry Metallurgy Research
ConOps concepts of operations

D

D Decision Applicatiions Division
DELTA Development of Lead-alloy Target Applications
DHS Department of Homeland Security
DoD Department of Defense
DOE Department of Energy
DTRA Defense Threat Reduction Agency
DX Dynamic Experiment Division

E

ECCS emergency core cooling system
EITAC Energy Infrastructure Training and Analysis Center
EIS Enterprise information security
EP Enterprise Project
EPRI Electric Power Research Institute
ESA Engineering Sciences and Applications Division
ESBWR enhanced simplified boiling water reactor

F

FCS Future Combat System
FMU Facilities Management Unit
FWO Facility and Waste Management Operations

G

GDS Genis Data System
GIAC Graphical Integrated Aggregated Control
GIS geographical information system
GUI graphical user interface

H

HE high explosive

I

ICAP Incident Characterization Action Plan
IEISS Interdependent Energy Infrastructure Simulation System
IIT information integration technology
INP integrated nuclear planning
ISI Infrastructure Security Initiative
ISR International, Space, and Response Technologies Division

J K

J Nuclear Nonproliferation Division
JIMO Jupiter Icy Moons Orbiter Project
JVB Joint Virtual Battle Laboratory

L

LANL Los Alamos National Laboratory
LANSCE Los Alamos Neutron Science Center
LDRD Laboratory directed research and development
LED logic evolved decision
LEP Life Extension Project
LOCA loss of coolant accident
LOS line of sight

M

MC02 Millenium Challenge 2002
MCMC Markov chain Monte Carlo
MCNPX Monte Carlo Neutron Photon Extended
MDA Missle Defense Agency
MISREPS mission history for mission reports
MPF Modern Pit Facility
MPI Message passing interface
MST Material Science Technology Division

N

N Nuclear Nonproliferation Division
NASA National Aeronautics and Space Administration
NATO North American Treaty Organization
NEPP Nuclear Earth Penetrator Project
NIMA National Imagery and Mapping Agency
NIMS National Incident Management System
NIS Nonproliferation and International Security
NISAC National Infrastructure Simulation and Analysis Center
NMT Nuclear Materials Technology Division
NNSA National Nuclear Science Administration
NRC Nuclear Regulatory Committee

O

OR/SA operations research/systems analysis

P

P Physics Division
PC personal computer
P&G Procter and Gamble
PM Project Management Division
PMBR Pebble Bed Modular Reactor
PF-4 Plutonium Facility
PRA Probalistic Risk Assessment
PVM Parallel virtual machine

Q

QMU Quantification of margins and uncertainties
QUIC Quick Urban and Industrial Complex

R

rdd radiological dispersion device
RF radio frequency
RNEP robust nuclear earth penetrator
RTBF readiness in technical base and facilities

S

S Security Division

T

TCP/IP Internet communications protocol
TITANS LANL Theoretical Institute of Thermonuclear and Nuclear Studies
TR Threat Reduction Directorate
TRAC Transient Reactor Analysis Code
TRACE TRAC/RELAP Advanced Computational Engine
TRANSIMS transportation simulator
TTD Tunnel Target Defeat

U

UC University of California
UNM University of New Mexico
UNWD Unconventional Nuclear Warfare Defense Program

V W

WEM weapons engineering and manufacturing
WMD weapons of mass destruction
WP weapons program

X Y Z

X Applied Physics Division
YADAS Yet Another Data Analysis System ▲

Professional Organizations

D Division is represented in the following professional organizations:

Air and Waste Management Association
American Anthropological Association
American Association for Rhetoric of Science and Technology
American Association for the Advancement of Science
American Chemical Society Association for Women in Science
American Economic Association
American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
American Mathematical Society
American Nuclear Society
American Physical Society
American Rock Mechanics Association
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Nuclear Engineers (ASNE)
American Society for Photogrammetry and Remote Sensing
American Society for Testing and Materials
American Sociological Association
American Statistical Association (ASA)
Association of Aviation Psychologists
Association for Computing Machinery
Association for Women in Science
Health Physics Society
Human Factors and Ergonomics Society
Institute of Electrical and Electronics Engineers (IEEE), APS, ACM
Institute of Mathematical Statistics
Institute for Operations Research and the Management Sciences (INFORMS)
Institute of Nuclear Material Management
Interface Foundation of North America
International Association of Energy Economists
International Society for Analytical Cytology
International Society for Bayesian Analysis (ISBA)
International Society for Optical Engineering (SPIE)
International Society for Rock Mechanics
International Society of Soil Mechanics and Foundation Engineering
International Test and Evaluation Association
LANL Reactor Safety Committee
Mathematical Association of America
Military Operations Research Society
National Academy of Sciences Panel on Estimating
New Mexico Network for Women in Science and Engineering
Operations Research Society of America
Phi Beta Kappa
Program Committee for the 2004 Congress on Evolutionary Computation
Project Management Institute
Rhetoric Society of America
Sigma Pi Sigma Physics Honor Society
Sigma Xi
Society of Environmental Toxicology and Chemistry
Society for the History of Technology
Society for Industrial and Applied Mathematics (SIAM)
Society of Mining Engineers of AIME
Society of Professional Engineers
Society for Risk Analysis
Society for Social Studies of Science
Tau Beta Pi

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L.M. Moore, "Computer Experiments: Designs to Achieve Multiple Objectives," 2003 Quality & Productivity Research Conference, Yorktown Heights, NY, May 2003.

L.M. Moore and T. Stephens, "Factors Controlling the Aging of S5370," Thirty-third Annual Polymac Conference, Amarillo, TX, 2003.

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K.M. Omberg "Alternative Career Paths of ACS Congressional Fellows," Invited Speaker, 226th American Chemical Society National Meeting, New York, NY, September 7–11, 2003.

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R.R. Picard, "Monitoring Syndromic Data for Detection of Clandestine Events," 2003 Annual Meeting of WNAR and IMS, Golden, CO, June 2003.

B.H. Sims, "Science vs. Bureaucracy? Safety and Institutional Culture at Los Alamos," Twenty-seventh Annual Meeting of Society for Social Studies of Science Annual Meeting, Atlanta, GA, October 15–18, 2003.

B.H. Sims, "The Eternal and the Ephemeral: Bridges, Disposable Diapers, and the Limits of Technological Change," Society for the History of Technology Annual Meeting, Atlanta, GA, October 16–19, 2003.

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